Basics of Hepatobiliary Interventions

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Foreword

I am pleased to write a foreword to Dr. Amar Mukund's book *Basics of Hepatobiliary Interventions*. Dr. Mukund who has been one of the pioneers in this subspecialty has been instrumental in establishing a robust protocol-based interventional management in liver diseases and portal hypertension, and I have been keenly observing his meteoric growth for over 10 years. He was key to establishing one of the most academic and vibrant departments at the Institute of Liver and Biliary Sciences (ILBS).

Interventional radiology has been one of the most dynamic, fascinating, and upcoming branch of medicine. Hepatobiliary interventions being a further superspecialized subdivision of interventional radiology provide a minimally invasive and intricate treatment option to patients with liver diseases. There has been an increasing need for skilled interventional radiologists in the management of sick patients before and after the organ transplant. Apart from having extremely sophisticated skills for successful procedure performance, it requires a deep understanding of the disease itself. The operator needs to maintain a delicate balance between treating a complicated disease and not causing complications while treating.

Being a new subspecialty there are very few dedicated textbooks on this subject. Moreover, there are only a few trained interventional radiologists working in the HPB field in the country. This book may serve as a guide for trainees and practicing interventional radiologists in this specialized field. This book provides a detailed but simple description of all relevant topics of hepatobiliary interventions. The contributors and editor should be congratulated for their efforts to create this book, which would not only benefit readers but also the patients in getting a highly sophisticated treatment and care. I am sure the feedback from readers and growth of hepatology would help the editor to improve the contents with every new edition, which I hope to see in the next few years.

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Preface

Liver disease is the latest epidemic affecting a majority of population and so is the need for management of various hepatic disorders, ranging from liver infection (abscess) to liver tumors, portal hypertension, and vascular diseases of the liver to post-liver transplant complications. Interventional radiology plays an important role in salvaging these conditions which are otherwise medically untreatable or unfit for surgery. Further it is an adjunct to various surgical procedures. During the course of my focused work on hepatobiliary interventions, I strongly felt the need for additional teaching and training in this subspecialty.

Interventional radiology being a rather new specialty with hepatobiliary interventions being further subdivision of the same, no book was available to shed light on the topic. So, I collaborated with various eminent and accomplished interventional radiologists, experts in their subspecialty, to give their valuable inputs into the making of this book with the intent to give the readers focused guidance into the subject. I feel this handbook will bridge this gap and cover most aspects of hepatobiliary interventions. This may serve as an important guide for the practicing interventional radiologist as well as the beginners wishing to pursue hepatobiliary interventions.

Further, I would like to add that the various changing facets of the medicinal practice and addition of advanced and newer technology and devices frequently remain a challenging matter, and hence, the readers should consider it as a basic handbook in this new subspecialty. The authors have worked hard compiling the chapters, and a further review of the content has been done by peers as well, despite some shortcomings; hence, I request all the readers to communicate and email their observations personally so that rectification of contents may be carried out subsequently. A further note of thanks to all the contributors for putting their hard work and completing the project in a reasonable time frame. Lastly, my heartiest gratitude to my readers for choosing this book.

New Delhi, India — Amar Mukund

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About the Editor

Amar Mukund, MBBS, MD completed his postgraduate certification in radiodiagnosis and later trained at Sanjay Gandhi Postgraduate Institute of Medical Sciences (SGPGIMS), Lucknow, and the All India Institute of Medical Sciences (AIIMS), New Delhi. He has been instrumental in establishing the interventional radiology wing at ILBS and pioneered hepatobiliary interventions. He has established the fellowship program (PDCC in HPB interventional radiology) at ILBS in 2012 and is the program director for the same. He has many peer-reviewed and indexed publications to his credit. Dr Mukund is an associate editor for the *Indian Journal of Radiology and Imaging* (IJRI) and has been an editorial board member/reviewer for many other journals. He has been a recipient of various prestigious awards and honors, e.g., the Young Investigator Award (ISVIR), Dr V P Lakhanpal Gold Medal, Dr Ashok Mukherjee Award, and Onco-imaging Innovation Award.

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1 Percutaneous FNA/Biopsy and Drainage Procedures

Krishna Bhardwaj, Chander Mohan, and Amar Mukund

Percutaneous nonvascular imaging-guided diagnostic as well as therapeutic procedures are one of the important tools in the armamentarium of interventional radiologist. These procedures are less invasive and can be performed on outpatient basis or daycare admission [1].

Percutaneous FNA/Biopsy is essential in establishing diagnosis and guiding further management protocol in various disease particularly with ongoing advances in oncologic treatment. Similarly, many conditions complicated by infected fluid collections were traditionally treated with open surgical drainage which was associated with high morbidity. Percutaneous drainage procedures have now become the treatment of choice in these conditions even in critically ill patients obviating the need for surgery [1].

In this chapter, we will discuss about basic technique, image guidance, indications, and contraindications of the percutaneous procedures with emphasis on procedures involving hepatobiliary system.

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1.1 Image Guidance

Percutaneous procedures are generally done under USG or CT guidance.

Ultrasound is the most common imaging modality used for guiding the procedure with many advantages like wide availability, portability, inexpensive, real-time visualization, shorter procedure time, ability to guide angled trajectory in any plane and lack of exposure to ionizing radiation (Fig. 1.1) [2]. However, for deep-seated lesions or in case of significant obesity visibility may be impaired and alternate imaging modality may be required.

Free hand technique is most commonly used with proper alignment of needle and axis of transducer for visualization of needle. Complete visualization of needle with ability to localise the needle tip while advancing the needle into the target is the key for successful procedure.

CT is advantageous in providing greater characterization of retroperitoneal and deep-seated structures [3] and precise planning of needle path particularly in retroperitoneal structures. It has the disadvantage of exposure to ionizing radiation with increased procedure time and difficulty in planning angular approaches [1, 3]. CT fluoroscopy can be used for real-time or intermittent visualization; however, it is limited by increased radiation dose [1].

MRI guidance is limited by cost constraints and need for dedicated MR compatible instruments [4].

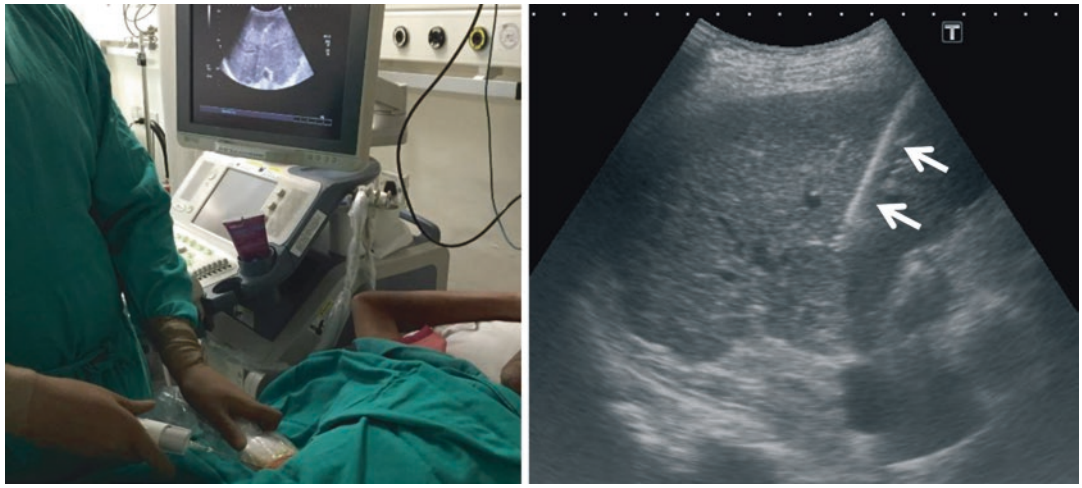

Fig. 1.1 Needle placement under USG guidance for liver lesion using free hand technique

Fusion imaging is helpful in cases where lesions are not clearly visible on gray-scale ultrasound. In this cross-sectional imaging, data are fed in the ultrasound machine and superimposed on real-time US images to locate the target lesion with help of electromagnetic markers and tracking software [4].

1.2 General Considerations

- The indication of the procedure should be properly defined and decision to be taken after multidisciplinary consultation with referral team and due consideration of all the risk involved. Patient's medical history, prior imaging, laboratory findings, etc. should be carefully reviewed by the interventional radiologist himself.
- Informed consent is a must before performing any kind of elective procedure with all the potential complication explained to the patient and his attendant, preferably in their own language.
- The choice of imaging modality should be based on the location of the lesion, available resources and operator experience. The planned needle path should be the safest and possibly shortest avoiding critical structures like blood vessels, large bowel, lung, etc. Small bowel or stomach can be safely transgressed with thin FNA needles [5].
- Evaluation of coagulation status is not required in low-risk procedures, however, should be routinely done in procedures with high risk of bleeding. In general platelet count of more than 50,000 platelets/μL and INR in the range of 1.5–1.8 can be used as threshold for moderate and high-risk cases otherwise should be corrected with the administration of blood components in peri-procedural period [6].
- Similarly, the antiplatelet medication and anticoagulants need not to be withheld before low-risk procedure. In cases of high-risk procedures Aspirin and Clopidogrel should be withheld five days before procedure. Low molecular weight heparin (LMWH) should be withheld for one or two doses for high-risk procedure. The patient's individual risk should also be taken into consideration before these strategies like recent history of bleeding, coagulopathic disorders, etc. Bridging therapy with heparin can be considered in patients with increased risk of thrombosis [6].
- Most of the procedures can be done under local anesthesia with minimal sedation. Nil per oral (6 h for solids and 2–3 h for clear liquids) is only required in deeper lesions and those requiring moderate sedation [7].
- Intravenous access should be secured before the start of the procedure. Moderate sedation should be preferably administered by anesthesiologist with all the equipment's available for

monitoring of vital parameters and emergency resuscitation [8, 9].
- Optimal positioning of the patient is required depending upon the planned trajectory.
- Strict asepsis should be maintained in all the procedures. Routine use of periprocedural antibiotic cover is recommended only in cases with infected collections or any ongoing sepsis.
- The sample should be correctly labeled and promptly transported to the laboratory for further analysis.
- Post-procedure patients should be screened for any complications and kept under observation for few hours before discharge. The complications, if any should be promptly identified and managed accordingly. Patient and their attendants should be advised to report to emergency in case of any procedure-related complication observed after getting discharged from the hospital.

1.3 Percutaneous FNA/Biopsy

Percutaneous needle biopsy (PNB) means procuring sample of tissue, cells, or fluid for diagnosis through image guided percutaneous insertion of needles into a suspected lesion or organ [8]. PNB thus helps in confirmation of clinical diagnosis and planning management algorithm.

PNB consists of Fine Needle Aspiration (FNA) using thin Spinal needles 22–25G for aspirating cells for cytopathological analysis or Core Biopsy (CB) using needles/devices 20G or larger to obtain tissue for histopathological analysis which are required for tissue architecture like in lymphoma or any other tumor subtype detailed analysis.

Core biopsy is done mostly by True-Cut needles/devices with spring-loaded side-cutting mechanism consisting of the outer cannula and inner notched trocar.

True-Cut needles/devices can be of semiautomatic or automatic firing mechanism (Fig. 1.2) [2]. In fully automated biopsy guns, both steps of forward advancement of central trocar and cutting cannula are automated and rapid, whereas in semiautomated devices inner trocar is manually advanced. The manual placement of trocar ensures more precise targeting with lesser chance of injury to surrounding critical structures. However sometimes the target lesion can be displaced while forwarding the trocar. In case of fully automated systems before firing, needle tip position should be calculated/anticipated while positioning the biopsy gun to avoid any inadvertent injury.

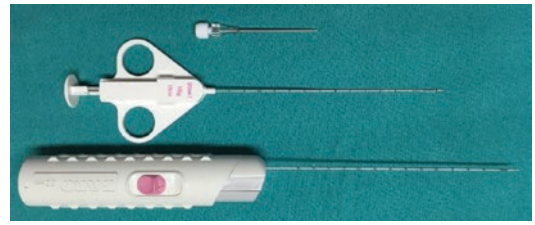

Fig. 1.2 Different type of biopsy needles/devices. Automatic biopsy device, semiautomatic biopsy device, and coaxial needle for obtaining multiple sample from single needle puncture (from bottom to top)

Coaxial needles can be used when multiple tissue cores are required thus avoiding multiple passes. It theoretically reduces the procedure time and chance of bleeding; however, studies comparing coaxial and non-coaxial methods show similar complication rates. This can be explained by larger bore of coaxial needle and longer dwell time. Coaxial needles can also be used in plugged biopsies for embolizing the needle tract using gelfoam slurry or embolization coils [1].

The choice of needle length depends upon the distance of the target lesion from the skin, whereas needle throw size depend on the size of the lesion.

1.4 Indications and Contraindications

The main indications for image guided percutaneous needle biopsy are as follows [8–10]:

1. To confirm the nature (benign or malignant) of the suspected lesion and its staging in case of tumor spread or metastasis.

2. To obtain tissue for molecular analysis thus aiding in the classification of certain malignancies and subsequently in guiding the therapy and monitoring the treatment.
3. To obtain material for microbiologic analysis in patients with proven or suspected infections
4. To pathologically confirm the nature and extent of diffuse parenchymal diseases (liver and renal parenchymal disease, graft rejection, etc.).

The contraindications are few with most of them being relative contraindication after considering risk versus benefits like uncorrectable coagulopathies, absence of a safe access path, ascites, severe cardiopulmonary insufficiency or hemodynamic instability and patient inability to cooperate or proper positioning not possible [8–10].

1.5 Percutaneous Drainage/ Aspiration

Percutaneous drainage procedures are minimally invasive methods to deal with abnormal fluid collections/abscesses which needs to be evacuated for fast recovery or not responding to medical management [7]. Drainage procedures may be of two types: Percutaneous catheter drainage with continuous drainage by indwelling catheter or single time aspiration where needle or catheter is removed after drainage.

Different techniques—Trocar or Seldinger—are used depending upon the indications, operator choice, etc with their own advantages or disadvantages [1, 7, 11].

Trocar technique is a simple and one step procedure where a catheter mounted over a trocar is inserted directly under image guidance inot the collection/abscess. It is useful in superficial easily accessible lesions and in bedside procedures. However, chances of injury to adjacent structures while inserting the drainage catheter are more with this technique as compared to Seldinger technique.

In Seldinger technique access is established by 18G needle and subsequent passage of 0.035 inch guidewire. Sometimes 21G needle are used with 0.018 inch guidewire. Coaxial dilator and sheath system are used for converting 0.018 system into 0.035 system [12–14]. The tract is serially dilated with fascial dilators up to or just more than the required catheter size followed by catheter deployment over the guidewire. A 8–12 F drainage (pigtail or Malecot) catheter should be inserted over the guidewire into the cavity under direct sonographic guidance. After removing the guidewire, catheter is fixed to the skin using skin sutures and connected to the collection bag [13, 14]. After placement, proper catheter care is required to avoid accidental removal or kinks within the catheter/connecting tubes. The catheter should be gently irrigated using 5–10 ml saline with all aseptic precautions two to three times daily to maintain the patency of the catheter [13, 14].

Seldinger technique is more controlled and suitable for deeper lesions like in retroperitoneum. However, due to multiple steps involved it requires assistance and is time consuming as compared to trocar technique. In certain cases like Hydatid cyst there is theoretical risk of fluid leakage during the manipulation of guidewire and dilators.

1.6 Indications and Contraindications

The indications for image guided percutaneous drainage/aspiration are to characterize the nature of the fluid collection or to relieve any symptoms due to sepsis or pressure effect [14, 15].

The contraindications are same as discussed above for PNB.

1.7 Organ Specific Special Considerations

1.7.1 Liver Parenchymal Biopsy

Liver biopsy plays an important role in diagnosis, staging, and planning management of diffuse parenchymal disease [16]. Another important role of liver biopsy is to establish diagnosis in case of deranged liver function in transplant

recipients. It helps in differentiating graft rejection from other etiologies.

The US guided percutaneous liver biopsy is safe and results in lesser complications as compared to blind approch as it helps in selection of relatively avascular area avoiding larger intrahepatic vessels [17, 18]. Generally right lobe is preferred through low intercostal or subcostal approach; however, either right or left lobe approach can be used depending upon the sampling requirement, operator or institutional preference. Left lobe subxiphoid approach is associated with lesser risk of pleural transgression.

Tissue sample measuring 1.5 cm mostly suffices as a tissue containing 6–8 portal triads is considered adequate [19]. The tissue sample is mostly obtained by inserting 16/18G automated or semiautomated biopsy devices. Coaxial needles (17G if 18G biopsy needles are used) can be used to avoid multiple insertions and for performing plugged biopsy.

Complications are mostly rare with pain and mild hypotension due to vasovagal phenomenon being most frequent minor complications. Localized intraparenchymal or subcapsular hematomas can also be seen and are managed conservatively. The most serious complication consists of active intraperitoneal hemorrhage, which is rare but needs immediate intervention [19]. Fluid resuscitation should be started immediately and CT angiography should be done and transcatheter embolization of the bleeding vessel should performed along with blood tranfusion as per the requirement.

Plugged biopsy reduces the risk of post-procedure bleeding in patients at high risk of bleeding [20]. It is easier to perform than transjugular biopsy (TJLB) and is procedure of choice especially in transplant recipients [21]. Gelfoam is commonly used agent (Fig. 1.3) though various other agents like coils or glue may also be used. The risk of bleeding can be further reduced by manually compressing the skin entry site or by positioning the patient ipsilateral side down.

1.7.2 Liver Abscess

Image guided percutaneous drainage combined with broad spectrum intravenous antibiotics has become the mainstay of treatment for pyogenic and amoebic liver abscesses, refractory to medical treatment alone. Surgical interventions are

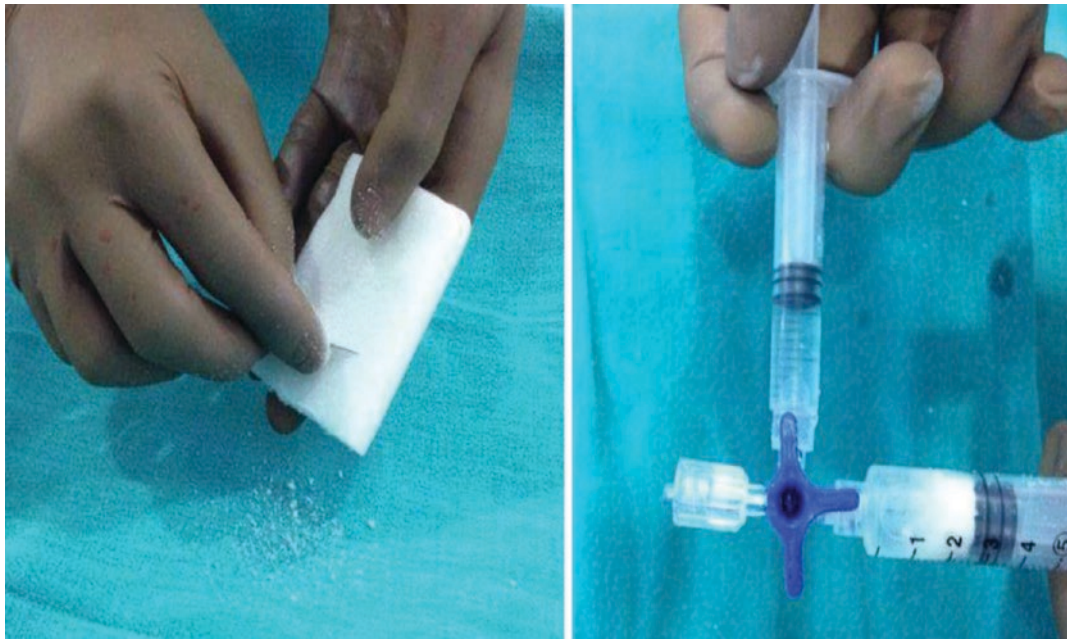

Fig. 1.3 Preparation of gelfoam slurry

usually reserved only for those patients failing to respond to percutaneous minimally invasive methods [22]. Percutaneous catheter drainage with indwelling catheter appears to be more effective; however, needle aspiration can be alternatively used with similar efficacy in abscesses smaller than 50 mm in largest diameter [23, 24]. For multiple abscesses, drainage using multiple catheters for large abscesses and needle aspiration for smaller abscesses may be performed.

Under real-time US guidance 18G Chiba or Spinal needle can be used for single time aspiration. Puncture should be done with a rim of normal liver parenchyma before entering into the abscess cavity avoiding vessels or dilated biliary channel.

Similarly, PCD is done by Seldinger or Trocar technique and 8–12 Fr catheter can be placed for continuous drainage [7]. After placement the catheter is sutured to the skin and connected to the collection bag. After the procedure the connections and catheter hygiene is regularly evaluated at follow-up. Follow-up should be done for catheter position and drain output. Frequent flushing with normal saline should be done to prevent catheter blockage. Catheters can be removed if there is no or insignificant liquefied contents on imaging and output falls to less than 10 mL per day for two to three consecutive days. Persistent high output may suggest biliary communication.

1.7.3 Splenic Interventions

Percutaneous interventions in spleen are infrequently done due to relative low incidence of splenic involvement and concerns regarding high risk of complication, particularly hemorrhage [25, 26]. However, image guided procedures like splenic biopsy, fluid aspiration, and catheter drainage are considered safe and clinically effective [27].

The main indications for splenic FNA or biopsy are to determine the etiology of focal lesion and to sometime evaluate splenomegaly of unknown cause [27]. The most common clinical indication being focal splenic lesion in known or suspected case of lymphoma or extra-splenic malignancy [25, 27].

Splenic abscesses are generally rare and usually treated with antibiotics and splenectomy, however, recent trend is toward spleen preserving approach. Minimal invasive percutaneous treatment shows comparable effectiveness and success rate to surgery and has the advantage of avoiding splenectomy related complications [25, 26].

Pre-procedure imaging evaluation should be done beforehand to plan the access path in a manner to traverse the least amount of splenic parenchyma [11]. Most of the procedures are done under the US guidance with subcostal approach avoiding adjacent structures like colon, kidney, lung, and pleura. Limited pleural transgression is considered safe in case of biopsies or FNA, however, not in catheter drainage [27].

The major complication is hemorrhage with lesser risk in FNA compared to core biopsy. Small hematomas can be managed conservatively whereas life-threatening hemorrhage requires urgent fluid resuscitation and blood transfusion with transcatheter embolization. Splenectomy may be needed in refractory cases [25].

1.7.4 Percutaneous FNA/Biopsy in Pancreatic Lesions

Pancreatic adenocarcinoma is one of the leading causes of cancer-related deaths with dismal 5-year survival rate, therefore accurate diagnosis by cytological or histopathological analysis is of paramount importance. Percutaneous image guided, endoscopic or surgical procedures are performed for obtaining samples [28]. With advancement in endoscopic ultrasound (EUS) and its ability to obtain cytological sample, EUS guided FNA has become the procedure of choice for diagnosis and staging of pancreatic lesions with lesser rate of complications and similar accuracy compared to percutaneous FNA [29]. However, in places where EUS is not available, percutaneous image guided methods can be used. Limitations of percutaneous sampling include lack of safe path or difficulty in visualising body or tail region of pancreas and marginally increased risk of complications [29].

Direct access should be preferred but frequently not possible, so transhepatic or transgastric approach may be used in difficult situations [28].

1.7.5 Postoperative Collections

Postoperative intra-abdominal collections are important cause of morbidity in post-surgical patients. Majority of them can be managed by percutaneous drainage mostly using ultrasound or CT guidance. Different approaches are used keeping in mind the location of collection and proximity to vital structures.

Subphrenic collections are quite common in upper abdominal surgeries. Generally subcostal or low intercostal approach is used with angled needle trajectory to avoid pleural transgression [11]. Similarly, deep pelvic collections can be accessed by trans-gluteal, transrectal or transvaginal approaches [30].

Appendix

Basic knowledge of the hardware for these procedures is mandatory for IR persons for optimal results. Tables 1.1 and 1.2 comprises of list of hardware needed in basic percutaneous procedures which can be tailored as per individual procedures [1].

Table 1.1 General hardware requirement for percutaneous FNAC/biopsy procedures

FNAC
Local anesthetic agent
Disposable syringes
22–25G spinal needle (Chiba needle in case of deeper Lesions)
Slides
Core biopsy
Local anesthetic agent
Surgical blade no. 11
Automated or semi-automated Biopsy Gun 14–20G with throw 10–20 mm
Coaxial Needle (if multiple passes or plugged biopsy with geofoam)
Sample collection boxes (containing formalin and/or normal saline)

Table 1.2 General hardware requirement for percutaneous drainage procedures

Local anesthetic agent
Surgical blade no. 11
Disposable syringes
Catheter loaded with Trocar (in case of Trocar technique)
Seldinger technique
Introducer needle 18G
0.035-inch stiff guidewire (90/145 cm)
Fascial dilators (6–8 Fr up to the required size)
Drainage catheter
Collection bag with connectors
Sample collection boxes
Suture/fixation device

References

1. Mukund A, Bhardwaj K, Mohan C. Basic interventional procedures: practice essentials. Indian J Radiol Imaging. 2019;29(2):182–9.
2. Kim JW, Shin SS. Ultrasound-guided percutaneous core needle biopsy of abdominal viscera: tips to ensure safe and effective biopsy. Korean J Radiol. 2017;18(2):309–22.
3. Schiavon LHO, Tyng CJ, Travesso DJ, Rocha RD, Schiavon ACSA, Bitencourt AGV. Computed tomography-guided percutaneous biopsy of abdominal lesions: indications, techniques, results, and complications. Radiol Bras. 2018;51(3):141–6.
4. Lipnik AJ, Brown DB. Image-guided percutaneous abdominal mass biopsy: technical and clinical considerations. Radiol Clin North Am. 2015;53:1049–59.
5. Sainani NI, Arellano RS, Shyn PB, Gervais DA, Mueller PR, Silverman SG. The challenging image-guided abdominal mass biopsy: established and emerging techniques 'if you can see it, you can biopsy it'. Abdom Imaging. 2013;38(4):672–96.
6. Patel IJ, Rahim S, Davidson JC, Hanks SE, Tam AL, Walker TG, Wilkins LR, Sarode R, Weinberg I. Society of interventional radiology consensus guidelines for the periprocedural management of thrombotic and bleeding risk in patients undergoing percutaneous image-guided interventions—Part II: recommendations. J Vasc Interv Radiol. 2019;30(8):1168–1184.e1.
7. Kandarpa K, Machan L. Handbook of interventional radiologic procedures. 5th ed. Philadelphia: Lippincott Williams & Wilkins; 2016.
8. American College of Radiology. ACR–SIR–SPR Practice parameter for the performance of image guided percutaneous needle biopsy (PNB). Revised 2018 (Res. 14). Available from http://www.acr.org/*/media/ACR/Documents/PGTS/guidelines/PNB.pdf
9. Veltri A, Bargellini I, Giorgi L, Almeida P, Akhan O. CIRSE guidelines on percutaneous needle biopsy (PNB). Cardiovasc Intervent Radiol. 2017;40(10):1501–13. https://doi.org/10.1007/s00270-017-1658-5.

10. Gupta S, Wallace MJ, Cardella JF, et al. Quality improvement guidelines for percutaneous needle biopsy. J Vasc Interv Radiol. 2010;21:969–75.
11. Gervais DA. In: Gervais DA, Sabharwal T, editors. Interventional radiology procedures in biopsy and drainage. New York: Springer; 2011. https://doi.org/10.1007/978-1-84800-899-1.
12. Gervais D, Brown S, Connolly SA, Brec SL, Harisinghani MG, Mueller PR. Percutaneous imaging-guided abdominal and pelvic abscess drainage in children. Radiographics. 2004;24:737–54.
13. Wallace MJ, Chin KW, Fletcher TB, et al. Quality improvement guidelines for percutaneous drainage/aspiration of abscess and fluid collections. J Vasc Interv Radiol. 2010;21:431–5.
14. Nair AV, D'Agostino HR. Transcatheter fluid drainage. In: Valji K, editor. The practice of interventional radiology. Philadelphia: Saunders Elsevier; 2010. p. 106–25.
15. American College of Radiology. ACR-SIR-SPR Practice parameter for specifications and performance of image-guided percutaneous drainage/aspiration of abscesses and fluid collections (PDAFC). Revised 2018 (Res. 13) Available at https://www.acr.org/-/media/ACR/Files/Practice-Parameters/PDFAC.pdf
16. Rockey DC, Caldwell SH, Goodman ZD, Nelson RC, Smith AD. Liver biopsy. Hepatology. 2009;49:1017–44.
17. Vijayaraghavan GR, David S, Bermudez-Allende M, Sarwat H. Imaging-guided parenchymal liver biopsy: how we do it. J Clin Imaging Sci. 2010;1:30.
18. Farrell RJ, Smiddy PF, Pilkington RM, Tobin AA, Mooney EE, Temperley IJ, et al. Guided versus blind liver biopsy for chronic hepatitis C: clinical benefits and costs. J Hepatol. 1999;30:580–7.
19. Bravo AA, Sheth SG, Chopra S. Liver biopsy. N Engl J Med. 2001;344:495–500.
20. Tsang WK, Luk WH, Lo A. Ultrasound-guided plugged percutaneous biopsy of solid organs in patients with bleeding tendencies. Hong Kong Med J. 2014;20:107–12.
21. Atar E, Ben Ari Z, Bachar GN, et al. A comparison of transjugular and plugged-percutaneous liver biopsy in patients with contraindications to ordinary percutaneous liver biopsy and an "in-house" protocol for selecting the procedure of choice. Cardiovasc Intervent Radiol. 2010;33:560–4.
22. Cai YL, Xiong XZ, Lu J, et al. Percutaneous needle aspiration versus catheter drainage in the management of liver abscess: a systematic review and meta-analysis. HPB (Oxford). 2015 Mar;17(3):195–201.
23. Rajak CL, Gupta S, Jain S, Chawla Y, Gulati M, Suri S. Percutaneous treatment of liver abscesses: needle aspiration versus catheter drainage. AJR Am J Roentgenol. 1998;170:1035–9.
24. Zerem E, Hadzic A. Sonographically guided percutaneous catheter drainage versus needle aspiration in the management of pyogenic liver abscess. AJR Am J Roentgenol. 2007;189:W138–42.
25. Singh AK, Shankar S, Gervais DA, Hahn PF, Mueller PR. Image guided percutaneous splenic interventions. Radiographics. 2012;32(2):523–34.
26. Kang M, Kalra N, Gulati M, Lal A, Kochhar R, Rajwanshi A. Image guided percutaneous splenic interventions. Eur J Radiol. 2007;64(1):140–6.
27. Sammon J, Twomey M, Crush L, Maher MM, O'Connor OJ. Image-guided percutaneous splenic biopsy and drainage. Semin Interv Radiol. 2012;29:301–10.
28. Tyng CJ, Almeida MF, Barbosa PN, et al. Computed tomography-guided percutaneous core needle biopsy in pancreatic tumor diagnosis. World J Gastroenterol. 2015;21(12):3579–86.
29. Okasha HH, Naga MI, Esmat S, et al. Endoscopic ultrasound-guided fine needle aspiration versus percutaneous ultrasound-guided fine needle aspiration in diagnosis of focal pancreatic masses. Endosc Ultrasound. 2013;2(4):190–3.
30. Maher MM, Gervais DA, Kalra MK, et al. The inaccessible or undrainable abscess: how to drain it. Radiographics. 2004;24:717–35.

Percutaneous Biliary Procedures

2

Kumble Seetharama Madhusudhan

2.1 Introduction

Percutaneous biliary interventions (PBI) are common procedures performed in the management of various pathologies involving the biliary system. They mostly include percutaneous transhepatic biliary drainage (PTBD), biliary stenting (BS), and percutaneous cholecystostomy. An interventional radiology (IR) specialist plays a pivotal role in performing these procedures and has become an integral part of the multidisciplinary team managing patients with biliary diseases. In view of increasing incidence of various biliary diseases, e.g., gallbladder cancer, postsurgical biliary complications, the need for these procedures has increased tremendously. Hence, a thorough knowledge of these biliary procedures is necessary for optimal patient management. This chapter describes the indications, contraindications, basic steps, and complications of various biliary interventions.

2.2 Hardware

A complete familiarity with the required hardware is necessary for performing any successful intervention. The hardware necessary for PBI is shown in Figs. 2.1 and 2.2. The list is not exclusive and the IR specialist may choose any other hardware which he or she feels appropriate for the procedure.

The puncture needle chosen, usually 17G or 18G, should allow passage of a 0.035 inch guidewire. Its length should be appropriate (7–15 cm), as a too long needle will be difficult to control and a too short needle may not reach the target. This should be assessed prior to the procedure. For non-dilated or mildly dilated system, 21G or 22G needle with 0.018 guidewire is used.

The soft, teflon coated, hydrophilic guidewire (0.035 or 0.032 inch, 145 cm long) is used to obtain access after the initial puncture and for crossing the strictures. The extrastiff or ultrastiff guidewire (0.035 inch, 145 cm long) is used during dilatation of the tract or stricture, placement of catheters, and deployment of stents. Longer length of stiff wire (260 cm) may be necessary when stents are deployed, especially ones with long shaft length (135 cm). Dilators required depend on the final size of the catheter placed, usually range from 6F to 12F. A 8F catheter is usually sufficient to drain the bile in most situations. Only when there is too much debris or sludge in the biliary system, a large bore catheter (10F or 12F) is necessary for drainage. The caliber of the metallic biliary stents used is usually 8 mm or 10 mm, usually self-expandable uncovered stents. The length varies, depending on the length of the stricture. Cytology brush and biopsy

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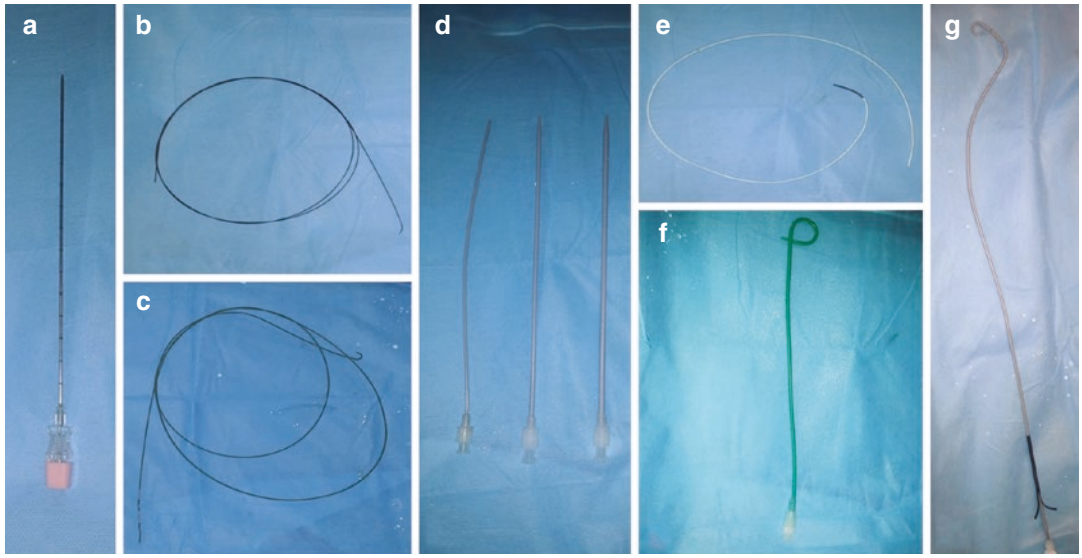

Fig. 2.1 Hardware used for PTBD. (**a**) 18G, 15 cm long two-part puncture needle. (**b**) Soft hydrophilic J-tip 0.035 inch guidewire. (**c**) Extrastiff 0.035 inch guidewire. (**d**) Serial dilators. (**e**) Short length angled 5F catheter for biliary manipulation. (**f**) 8F pigtail catheter for external drainage. (**g**) 8.3F ring biliary catheter for internal–external drainage

forceps are used when the diagnosis of malignant or indeterminate strictures has failed by standard techniques.

2.3 Methods of Drainage

There are three methods of drainage (Fig. 2.3) [1]. First is *external* drainage, wherein a pigtail/malecots catheter is placed proximal to the obstruction, to allow the bile to drain to an externally connected bag (Fig. 2.3a). This, however, cannot be a permanent solution as there is a loss of fluid and bile salts which cause dehydration and electrolyte imbalance. Thus, internal drainage should always be attempted. But in some situations like where the stricture could not be crossed or there is cholangitis, external drainage catheter is placed. Combined, i.e., *internal–external* drainage is placed in such a way that there are holes in the catheter proximal and distal to the stricture (Fig. 2.3b). This allows the bile to flow into the duodenum resulting in normal anatomical drainage. The external portion of the catheter may be connected to a bag for external drainage. Internal drainage is done after internalization and resolution of cholangitis. This catheter has the advantage of better stability, reduced loss of fluids, and the option of allowing internal drainage whenever necessary after capping the external end and an option of external draibage if internal drainage is not optimal. The third type is total *internal* drainage when the bile is drained only internally (Fig. 2.3c). This is possible by either capping the external end of the internal–external drainage catheter or by placing a biliary stent.

2.4 Percutaneous Transhepatic Biliary Drainage (PTBD) for Malignant Biliary Obstruction

PTBD, as the name indicates, is a percutaneous interventional procedure performed for the drainage of the bile, externally, internally, or both, through a catheter positioned in the biliary tract. Malignancies causing biliary obstruction, like gallbladder cancer or cholangiocarcinoma, result in the dilatation of intrahepatic bile ducts (IHBD).

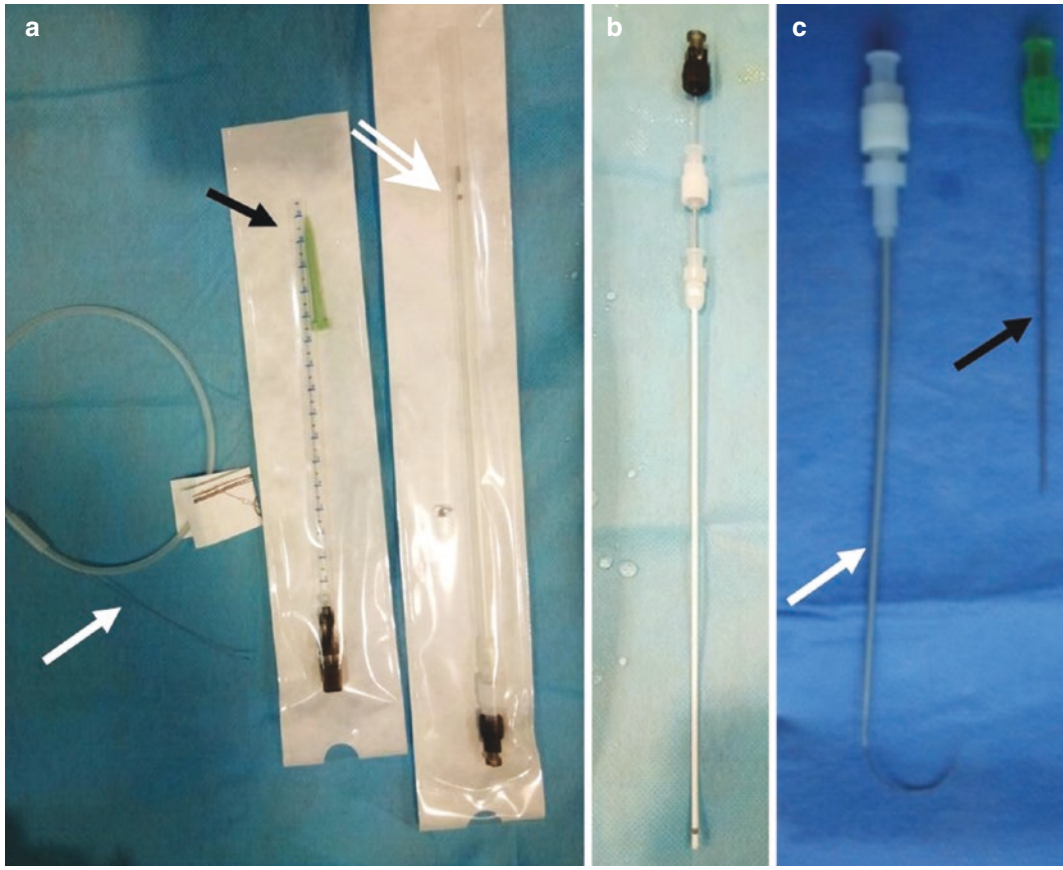

Fig. 2.2 Hardware for non-dilated biliary system. (**a**) Set of accessories including 22G, 15 cm puncture needle (black arrow), 0.018 inch guidewire (white arrow), and three-part introducer set (open arrow). (**b**) Introducer set with central stiffening canula, and coaxial 4F and 6F sheaths. (**c**) Another set with 21G, 7 cm needle (black arrow), and 5F coaxial dilator with 0.018 inch guidewire (white arrow)

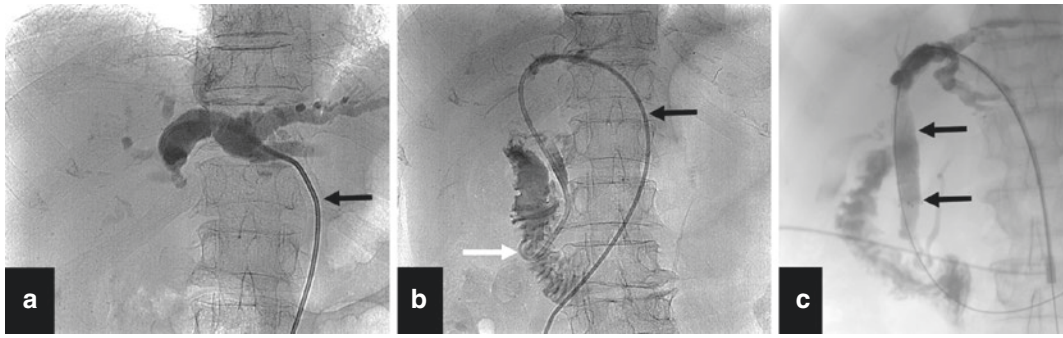

Fig. 2.3 Methods of biliary drainage. (**a**) External drainage where pigtail catheter (arrow) drains bile externally. (**b**) Combined external–internal drainage, where ring biliary catheter (black arrow) drains bile externally as well as internally through its tip in the duodenum (white arrow). (**c**) Internal drainage where a stent (arrows) drains the bile into the duodenum, allowing physiological drainage

The obstruction causes jaundice, pruritus, liver dysfunction, and cholangitis, due to stasis of bile [2, 3]. The purpose of PTBD is to relieve patient's symptoms (jaundice, pruritus), prepare the patient for chemotherapy or surgery (usually serum bilirubin <5 mg/dL) [4] and to drain infected bile (in cholangitis).

2.4.1 Indications

The most common indication for PTBD in malignant obstruction is cholestsasis with tumor-causing hepatic hilar obstruction, i.e., involving primary biliary confluence (high biliary obstruction). The advantage of PTBD is this situation is that one can choose which duct to drain and that when a stent is placed, the ampullary sphincter function is not disturbed [1]. Other indications include mid or low biliary obstruction where endoscopic biliary drainage (EBD) is either not possible due to patient's comorbid conditions or failed due to difficult anatomy or cannulation or in cases of altered anatomy (Roux-en-Y hepaticojejunostomy, Billroth II surgery, gastric bypass). PTBD is also indicated in patients presenting with acute cholangitis due to obstruction at any level, as the patient is often not fit for an EBD. Further, this is also the route for performing some biliary procedures like brush biopsy, radiofrequency ablation (RFA), and photodynamic therapy (PDT) [2, 5].

2.4.2 Contraindications

There is no absolute contraindication for performing a PTBD.

Relative contraindications include—deranged coagulation parameters, ascites, presence of skin site infection, large abscesses or tumors precluding a safe access route, lobar atrophy (unless it is infected), and uncontrolled hypertension. In patients with coagulopathy, which is not uncommon in these patients due to associated liver dysfunction caused by biliary obstruction, PTBD is done after its correction [6]. This can be done with fresh frozen plasma, if the indication for PTBD is urgent (e.g., cholangitis) or with correction after administering Vitamin K injection for few days, in nonurgent cases. Ascites increases the risk of bleeding during the procedure and makes the procedure technically difficult as the liver frequently gets pushed during the insertion of dilators or catheter. Also, there are higher chances of pericatheter leak of ascitic fluid. Hence, it should be drained as much as possible prior to PTBD. In patients with mild ascites, often there is no fluid anterior to the left lobe when the patient is in supine position, and a left PTBD is possible.

2.4.3 Clinical Presentation

Patients with malignant biliary obstruction usually present with painless progressive jaundice of short duration (usually few months). There may be associated loss of weight and appetite. Sometimes, high-grade fever with chills may be the initial presentation due to cholangitis. Laboratory investigations reveal elevated serum bilirubin (direct component), usually above 5–10 mg/dL. Alkaline phosphatase is also raised in these patients.

2.4.4 Pre-Procedure Imaging

As with any radiological intervention, prior imaging is necessary to plan a PTBD [2, 3]. Optimal imaging in these cases is typically a contrast enhanced computed tomography (CECT) scan (preferably multiphase as it helps in staging of the disease as well) or magnetic resonance imaging (MRI) with magnetic resonance cholangiopancreatography (MRCP). This gives information about the cause and level of obstruction. The level of obstruction determines whether a PTBD (high/hilar obstruction) or EBD (mid or low obstruction) should be done. The local staging of the disease helps determine the possible surgical procedure (hepatectomy or extended hepatectomy) and accordingly a right or left PTBD is decided. Similarly, the longitudinal extent of biliary involvement (i.e., involvement of secondary biliary confluence) also

determines the side to be drained (uninvolved side to be drained) and the need of multiple drains. It is important to drain the remnant liver and not the part of the liver which will be removed at surgery. The volume of the lobes or segments of the liver can also be evaluated, which again determines the lobe or segment to be drained. Ascites, when present, should be drained as described above.

2.4.5 Patient Preparation

Once it is decided that the patient needs PTBD, urgent or elective, the patient is to be prepared for the procedure. The patient should be admitted, in elective cases, at least 6 h prior to the procedure. A minimum of 4 h of fasting is necessary. Any derangement in the coagulation parameters should be corrected. Ascites, if present, should be drained. The international normalized ratio should be <1.5 and platelet count should be more than 50,000/mL [7]. The part (epigastrium to right later lower chest wall) should be prepared.

The patient should be given a dose of broad-spectrum antibiotic (penicillins or cephalosporins), 12 h prior to the procedure and continued for 2–5 days after the procedure [8]. We usually inject 1 g ceftriaxone intravenously. Adequate hydration is needed and intravenous fluids should be infused. The blood pressure (BP) should be measured. If high, a dose of antihypertensive medication should be given to bring the BP to normal.

2.4.6 Procedure of PTBD

Once the patient is prepared, he should be shifted to the fluoroscopy table in the interventional suite for the procedure. The patient is positioned supine and connected to the pulse monitor to check the vital parameters. Initial screening ultrasonography (USG) is done to check for dilatation of IHBD, level of obstruction, volume of the liver lobes/segments, status of primary and secondary biliary confluence, and ascites.

2.4.6.1 Selection of Site/Side

Depending on the findings on the initial imaging and USG at the time of the procedure, the site of PTBD is decided (Fig. 2.4). When the primary confluence is patent, either left or right-sided PTBD can be performed. When the primary confluence is blocked, the side should be chosen based on the type of surgery planned, involvement of secondary confluence, and the volume of the lobe drained.

2.4.6.2 Right PTBD or Left PTBD

Drainage of only 25–30% of liver parenchyma is sufficient to improve serum bilirubin level and improve liver function. Hence, in cases of hilar obstruction, drainage of one lobe is adequate. The left PTBD is more comfortable for the patient and there are fewer chances of pleural complications, but is associated with higher radiation dose and difficult manipulation [6]. In such situations, either right or left PTBD may be chosen. Our experience has suggested that there is no difference between right and left PTBD in terms of technical difficulty, radiation dose (to operator and patient), patient comfort, and complications [9]. However, since the most common cause of malignant biliary obstruction with hilar involvement is carcinoma of the gallbladder, a left PTBD is preferred as the left lobe of the liver is the remnant liver.

2.4.6.3 Preparation of the Part

Once the side of PTBD is decided, the area around the puncture site, beginning from the level of mid chest to the level of umbilicus, is cleaned with povidone-iodine and chlorhexidine solution. The area is draped with a long drape extending down to cover the lower limbs completely. This is helpful to maintain sterility of the long wires used during the procedure.

2.4.6.4 Anesthesia/Analgesia

The procedure is done under light to moderate sedation, using fentanyl, midazolam, propofol, and ketamine intravenously. Occasionally, patients may need general anesthesia. The site of puncture is anesthetized using 2% lignocaine, about 10 mL. It is injected along the puncture tract, from the liver capsule to the skin.

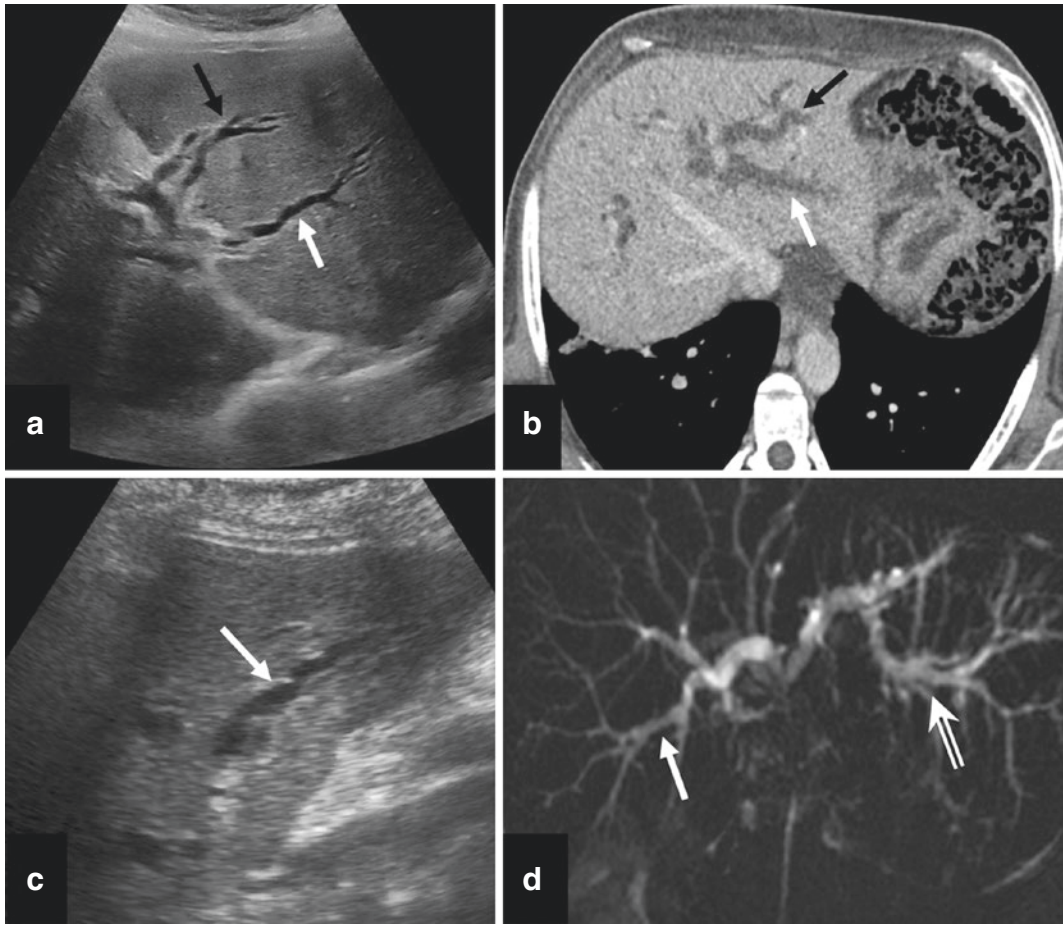

Fig. 2.4 Anatomy of segmental bile ducts of the liver. (**a, b**) Ultrasonography (**a**) and oblique axial CT scan (**b**) shows the relation of segment 2 (white arrow) and segment 3 (black arrow) ducts in the left lobe. Note that segment 3 duct is superficial and easier to puncture. (**c**) Ultrasonography of right lobe of the liver shows the segment 6 duct (white arrow) which is easier to puncture for right PTBD under ultrasonographic guidance. (**d**) MRCP image shows the preferred segment 3 duct (open arrow) and right posterior duct (arrow) for puncture as they form a smooth curve with common bile duct

2.4.6.5 Initial Puncture

Once the part is ready, it is important to identify a peripheral bile duct for puncture. Usually, the segment 3 duct on the left side and the segment 6 duct on the right side is preferred, as they are superficial and form a smooth curved course with the common bile duct (CBD) (Fig. 2.4) [6]. Segment 3 duct is superficial and more in line with the puncture compared to the segment 2 duct. Nevertheless, any duct may be punctured for drainage depending on the situations and the IR specialist's preference.

The puncture is best done under USG guidance (Figs. 2.5 and 2.6). Some may prefer to do it under fluoroscopic guidance as well. The USG probe is positioned in such a way that a 3–4 cm length of the duct is visualized. The point of puncture of the duct is important. Too peripheral puncture will result in the liver being pushed during manipulations, thus increasing the difficulty of the procedure. More central puncture increases the risk of hemorrhagic complications due to proximity to central vasculature. A reasonable site would be somewhere close to the

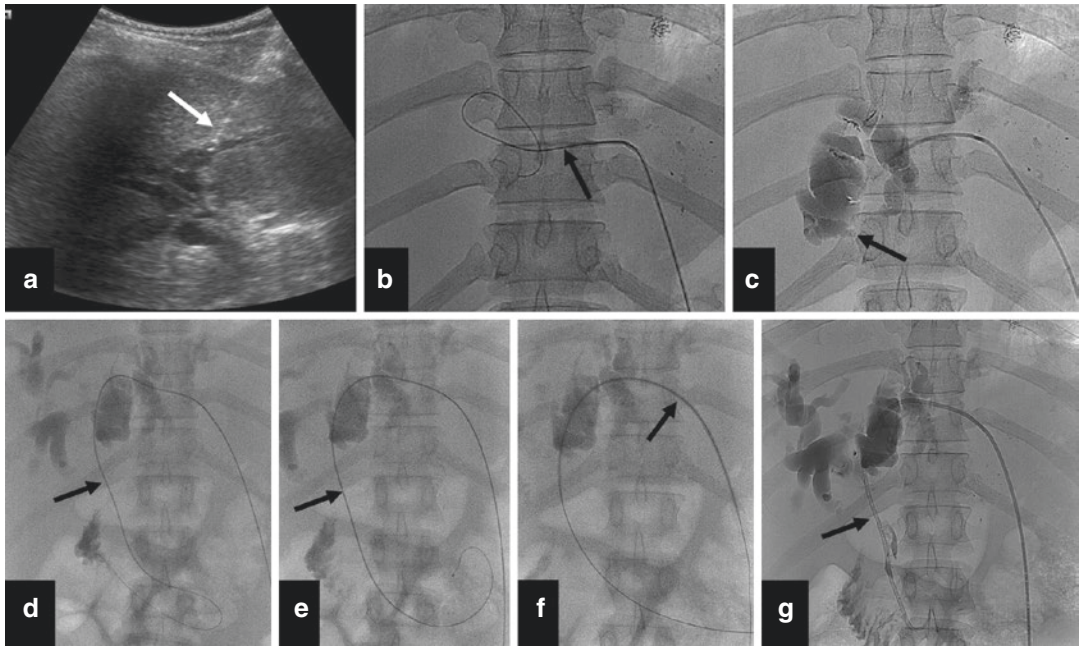

Fig. 2.5 Standard left PTBD. (**a**) Initial USG guided puncture (arrow) of segment 3 duct. (**b**) Exchanging the needle for 5F catheter (arrow) over a soft guidewire. (**c**) Initial cholangiogram showing the level of obstruction (arrow). (**d**) Soft guidewire (arrow) used to cross the stricture. (**e**) Extrastiff guidewire (arrow) replacing the soft guidewire. (**f**) Dilatation of the tract (arrow) and stricture. (**g**) Ring biliary catheter (arrow) allowing internal and external drainage

midpoint of the dilated segmental duct to be punctured, ensuring adequate surrounding parenchyma is present.

An 18G, 10 cm long, two-part needle is used for puncturing the duct. If the duct is only minimally dilated, a 21G or 22G needle should be used for the puncture. After the skin site is incised with a small surgical blade (No 11), the needle is advanced into the liver parenchyma toward the identified bile duct, under USG guidance. Once the needle tip is inside the duct, the trocar is removed to check for the backflow of bile. In an uninfected system, the bile is clear and light green in color. In infected cases, it is dark green and thick and may show debris or may be entirely purulent.

2.4.6.6 Cholangiogram

Once there is backflow of bile, a cholangiogram may be done at this point. However, it is not suggested, as there is a risk of displacement of the needle tip during this process. Hence, it is better to exchange the needle to a 5F catheter or 6F dilator over a soft hydrophilic guidewire (0.035 or 0.018 inch depending on the puncture needle used). This allows a longer length of the device (catheter or dilator) within the bile duct with secure access and thus less risk of displacement (Fig. 2.5b) [1]. Then a cholangiogram is done to identify the location and morphology of the obstruction (Figs. 2.5c and 2.6b).

While doing a cholangiogram, minimal diluted iodinated contrast should be used and contrast is injected gently and slowly to avoid it spilling into the obstructed undrained system. If it leaks, then there is a risk of chemical cholangitis caused by iodine itself. In cases of PTBD done for cholangitis, the use of contrast should be avoided, if possible or minimal contrast should be used to avoid bacteremia.

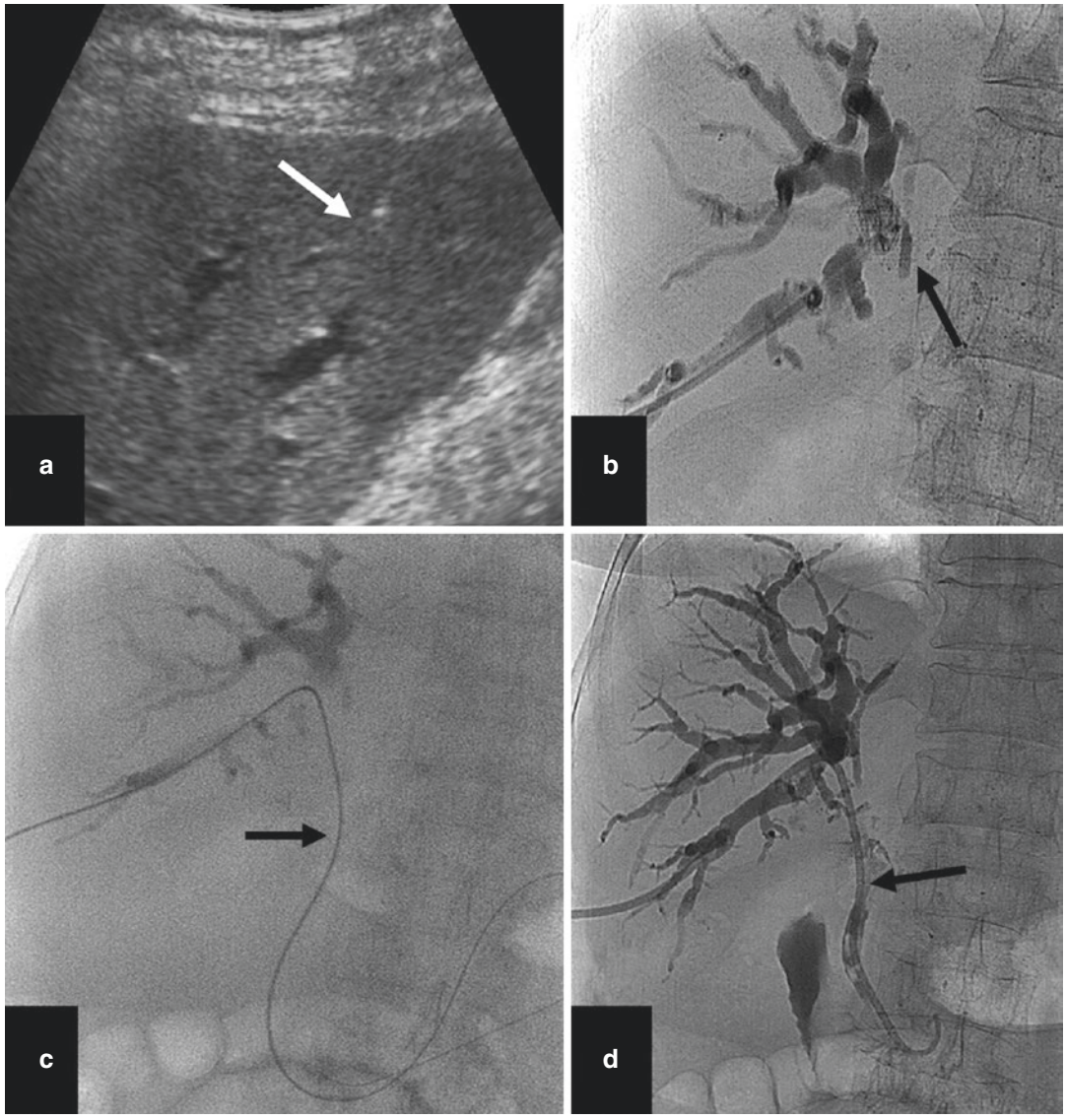

Fig. 2.6 Standard right PTBD. (**a**) Initial USG guided puncture (arrow) of segment 6 duct. (**b**) Initial cholangiogram with 5F catheter showing the level of obstruction (arrow). (**c**) Soft guidewire (arrow) used to cross the stricture. (**d**) Ring biliary catheter (arrow) allowing internal and external drainage, placed over an extrastiff guidewire

2.4.6.7 Crossing the Stricture (Internalization)

After localizing the level of obstruction with cholangiogram, the initial catheter or dilator is exchanged for a 5F KMP/multipurpose catheter (cut to a shorter length of about 35–40 cm) over a guidewire. With the tip of the catheter at the level of obstruction, J-tipped soft hydrophilic guidewire is used to cross the stricture (Figs. 2.5d and 2.6c). With a few attempts, the stricture can be crossed and the wire is passed through the ampulla into the third part of the duodenum. The catheter is pushed over the wire into the duodenum and the soft wire is exchanged for extrastiff or ultrastiff guidewire (Fig. 2.5e). The catheter is removed, leaving the wire in place.

In cases where the morphology of obstruction is rounded or when the dilatation is much,

crossing the stricture may not be possible. Then, the stiff guidewire is passed into the bile duct, proximal to the obstruction, for an external drainage. Internalization should be attempted at a later date. Once the biliary system decompresses, which usually occurs in about a week, it is less roomy and less inflamed. This results in a successful internalization in most cases.

2.4.6.8 Tract and Stricture Dilatation

After the stiff wire is in place, the tract and the stricture are dilated serially, initially with 6F and then with 8F dilators (Fig. 2.5f). Since the final catheter to be placed is of 8F or 8.3F, dilatation with 8F dilator is sufficient. But, occasionally, if the stricture is hard, over dilatation with 9F or 10F dilator may be needed. Over dilatation should usually be done if the final catheter does not easily slide over the wire across the stricture as over dilatation may have a potential risk of pericatheter leak.

Similarly, where the stricture has not been crossed, only the tract is dilated with 6F and 8F dilators over the stiff guidewire.

2.4.6.9 Placement of the Catheter

After dilating the tract, an 8.3F ring biliary catheter (for combined external and internal drainage) is placed over the wire, with few holes proximal as well as distal to the stricture (Figs. 2.5g and 2.6d). The position is confirmed by injecting iodinated contrast slowly so that the location of the proximal holes is clearly visualized. It is important to ensure that there are adequate number of holes proximal to the obstruction within the duct and there are no holes in the hepatic parenchyma. If so, the position should be adjusted over the stiff guidewire and reconfirmed with contrast. In cases where the stricture could not be crossed, an 8F pigtail catheter is placed for external drainage. In both cases, the free flow of bile should be seen from the catheter. Finally, the hub of the catheter is connected to a drain bag.

2.4.6.10 Catheter Fixation and Dressing

After satisfactory position of the catheter is confirmed, it should be fixed to the skin. Since these catheters are placed for a long time, especially in situations where PTBD is done for palliative purposes, adequate fixation is critical to prevent its dislodgement (Fig. 2.7). It is usually done with 2–0 suture (silk), which is used to suture the catheter to the surrounding skin. A stay suture may also be applied to further ensure its stability. Then, a small piece of gauze is placed at the skin site, surrounding the catheter over which stick tapes are applied. A technique that is followed is to place a pair of stick tapes on either side of the catheter, extending to the skin, to reduce the chances of dislodgement (Fig. 2.7b). Few fixation devices are also commercially available and avoid placement of suture, however, these require changing after few weeks (Fig. 2.7c).

2.4.6.11 Post-Procedure Monitoring

After the procedure, the patient should be observed for 4–6 h. The vital parameters should be continuously monitored. The drain and the dressing should be observed for any bleeding. Bloodstained bile may be seen after the procedure, which clears over 12–24 h. The dressing should also be observed for any soakage from bile. If the patient is stable after 6 h, he or she may be discharged. If PTBD is done for cholangitis, the patient should remain admitted until he or she is fit to be discharged.

2.4.6.12 Patient Instructions

At the time of discharge, few instructions should be given to the patient. These include:

1. Taking proper care of the catheter.
2. Monitor output from the catheter.
3. Adequate fluid intake to match for the bile loss.
4. To visit the hospital on the said date for internalization/capping of the catheter.
5. To visit the hospital in cases of fever, pericatheter leak, reduction in the drain of bile, blood in the drain, and blood-soaked dressing.

2.4.6.13 Capping

Once the stricture has been crossed (in first or subsequent attempts) and a ring biliary catheter is placed, the external end of the catheter should be closed or capped (Fig. 2.7d). This allows internal

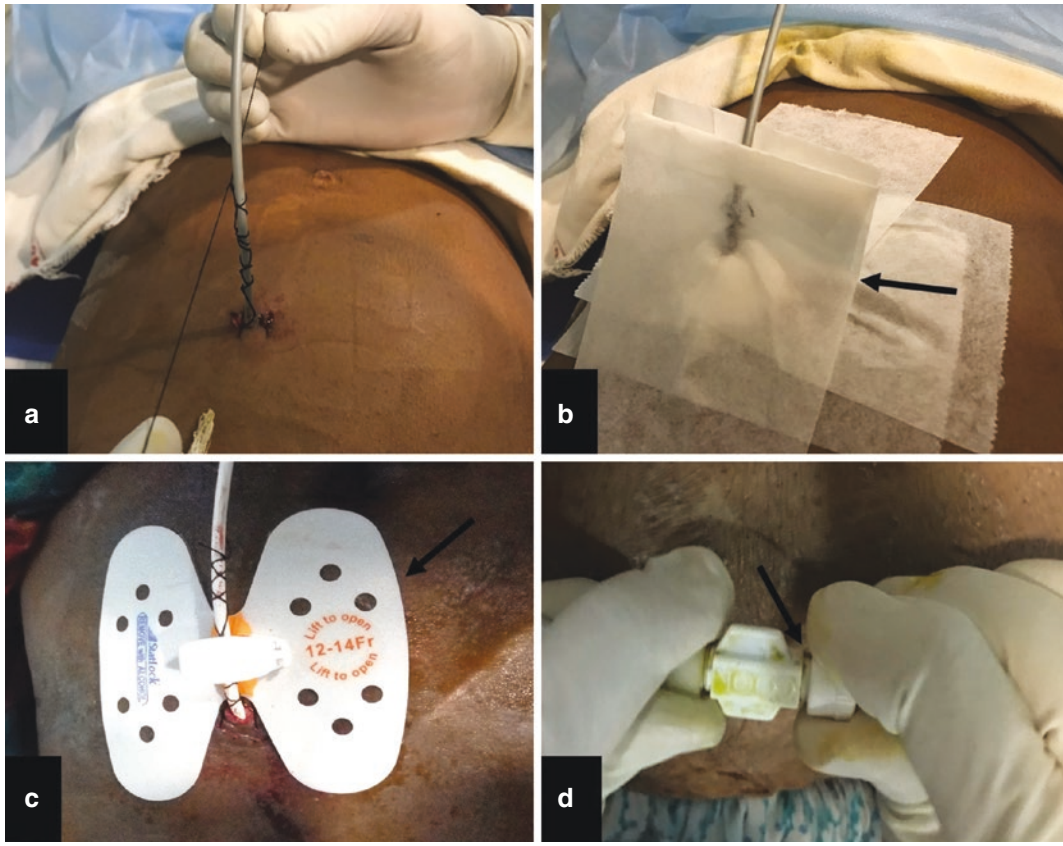

Fig. 2.7 Fixing the catheter. (**a**) Fixing the catheter with suture (2–0 silk). (**b**) Stabilizing the catheter with adhesive tapes (arrow). (**c**) Fixation device (arrow) used to fix catheters to skin. (**d**) Capping the ring biliary catheter (arrow) allowing internal drainage

drainage of the bile into the intestine allowing physiological drainage. External drainage results in loss of fluids and electrolytes, which should be balanced by adequate fluid intake. Once the catheter is capped, the drainage bag is not needed, which further improves the catheter's stability. Hence, internalization and capping of the catheter should be the aim of PTBD for malignant diseases as they are kept for a long duration.

Depending on the patient's requirement, morphology of the stricture, extent of hilar ducts involved and technical difficulty, unilobar or bilobar, and external or internal drainages are done (Fig. 2.8). Attempts should always be made to internalize the catheter. Multiple attempts (up to 5) may be necessary for some strictures with a gap of 1–2 weeks between two attempts.

2.4.7 Complications and Management

Since it is an invasive procedure, complications do occur. The incidence of the complications is in the range of 3–10% and mortality is very rare, with an incidence of <1% [10]. They can be classified into immediate and late. Immediate complications are the ones that occur within 48 h of PTBD. Late complications occur after 48 h. Any of the following complications can occur in the immediate or late period.

Bleeding—The incidence of significant bleeding is in the range of 2–2.5% in large centers [11]. The factors increasing the incidence of bleeding are renal failure, antiplatelet agents, multiple passes, central puncture, non-dilated

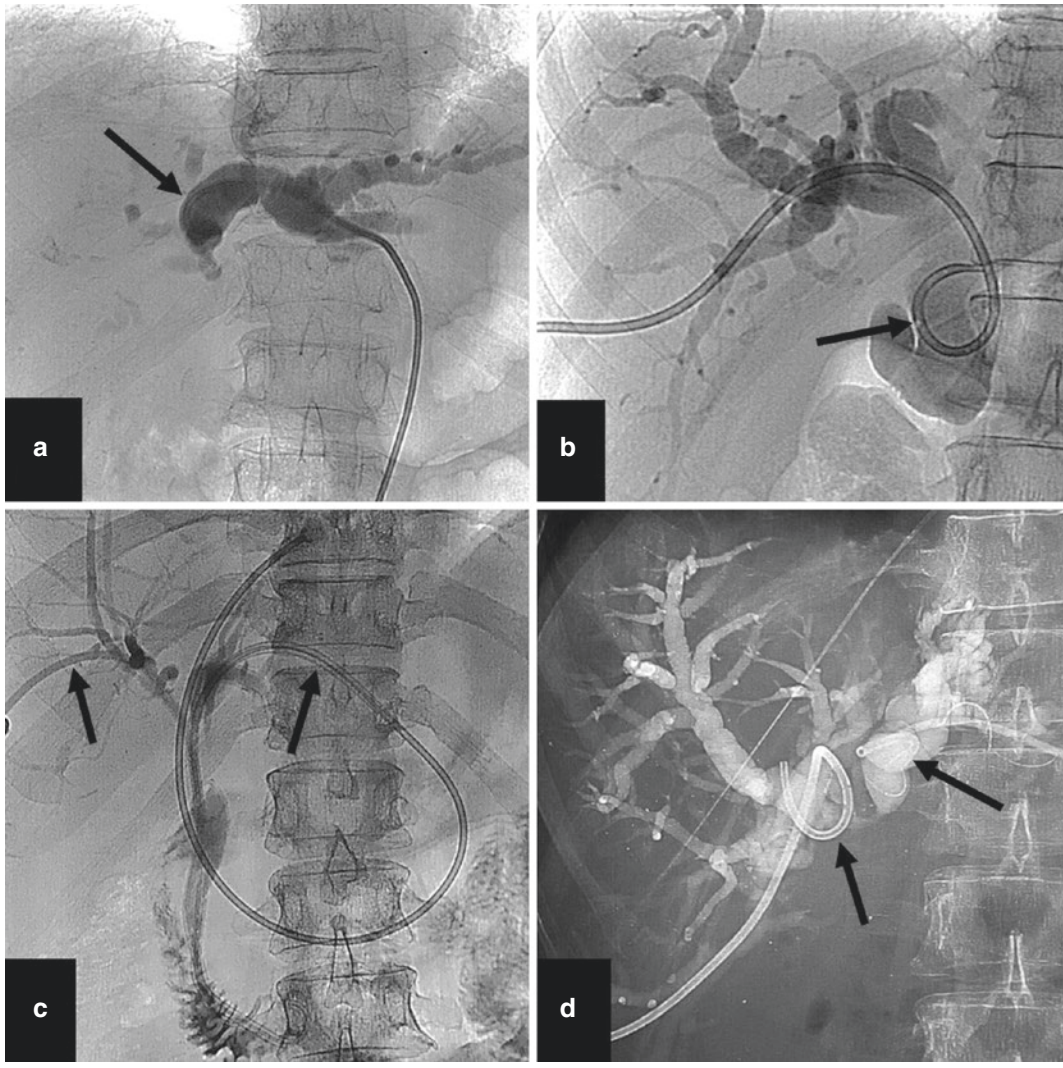

Fig. 2.8 Different types of drainage. (**a**) Left external drainage with pigtail catheter (arrow). (**b**) Right external drainage with pigtail catheter (arrow). (**c**) Bilateral external–internal drainage with ring biliary catheters (arrows). (**d**) Bilateral external drainage with pigtail catheters (arrows)

ducts, cirrhosis, and advanced age [12]. Majority of the bleeding complications (blood in the drain/hemobilia or pericatheter bleeding) are self-limiting. The patient should be observed for 24–48 h with the monitoring of vital parameters and gastrointestinal bleeding. The presentation is in the form of blood in drain, pericatheter bleeding, hematemesis or melena, or silent, when blood collects in the cavity like peritoneum, hepatic subcapsular space or pleural cavity. If the bleeding is persistent or if there is tachycardia or hypotension, the patient should be evaluated. After stabilization of the patient with blood products and intravenous fluids, the first thing to be done is a cholangiogram with iodinated contrast agent, to see if there are any holes of the catheter in the portal or hepatic vein or if there is any communication of the biliary system with hepatic artery or portal vein branches (Figs. 2.9 and 2.10). If holes of catheter are abnormally placed, it should be repositioned (Fig. 2.10a). If hepatic artery is opacified, then, depending on the

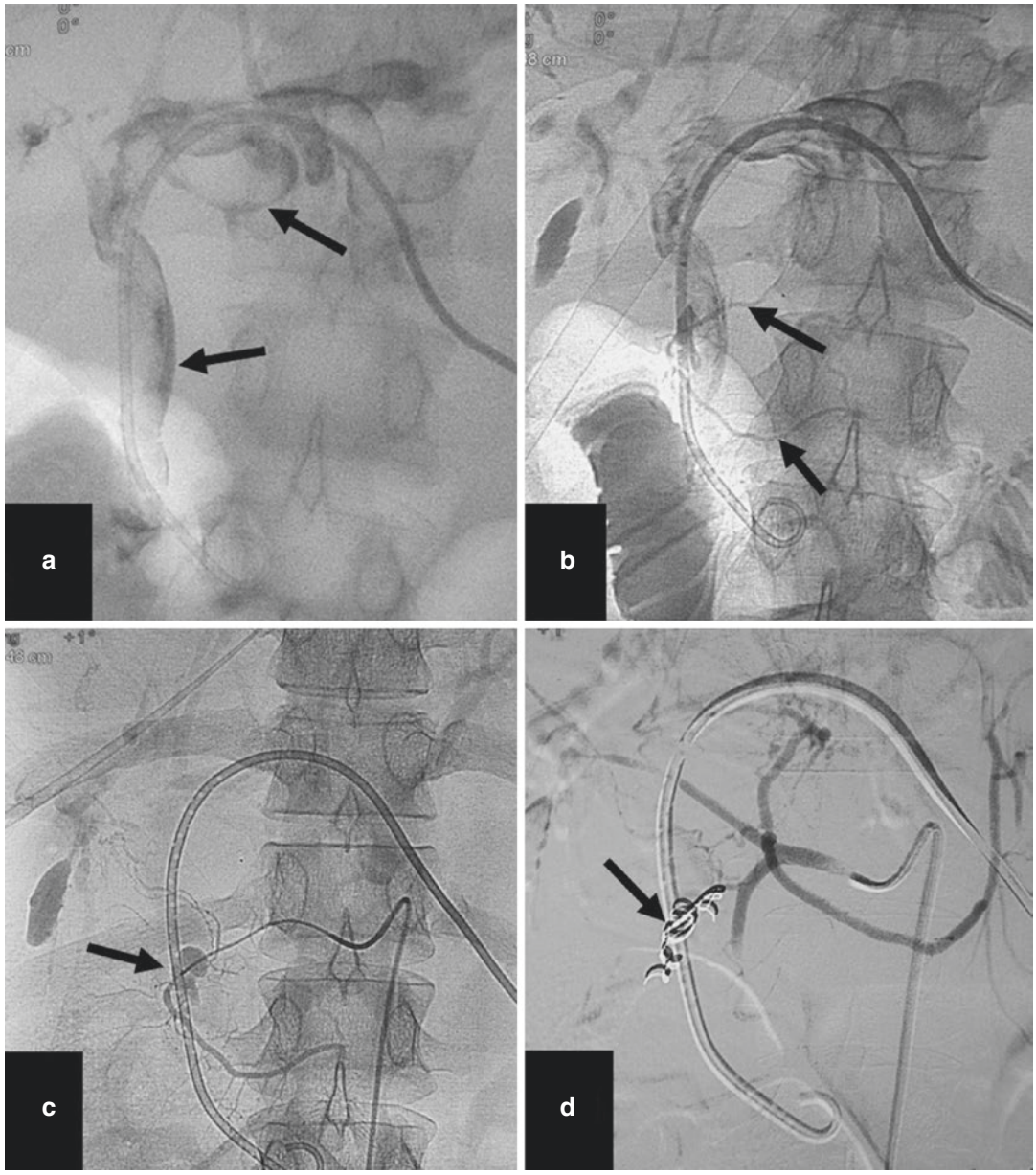

Fig. 2.9 Arterial injury. 30-year-old male presenting with bleeding from the ring biliary catheter, 1 week after PTBD. (**a**) Cholangiogram shows multiple filling defects (arrows) within the bile ducts suggesting clots. (**b**) On further contrast injection, gastroduodenal artery is seen opacified (arrows) close to the catheter. (**c**) Angiogram of gastroduodenal artery shows bilobed pseudoaneurysm (arrow). (**c**) Digital subtraction angiography shows embolization of the pseudoaneurysm with microcoils (arrow)

patient's condition, a CT angiogram followed by DSA or a DSA directly should be done (Fig. 2.9c). The bleeding artery should be catheterized selectively and embolized with coils (Fig. 2.9d) or n-butyl cyanoacrylate (NBCA). If portal vein is opacified, the management depends on the level of communication. If it is in the periphery, simple clamping of the catheter will cause the tampon-

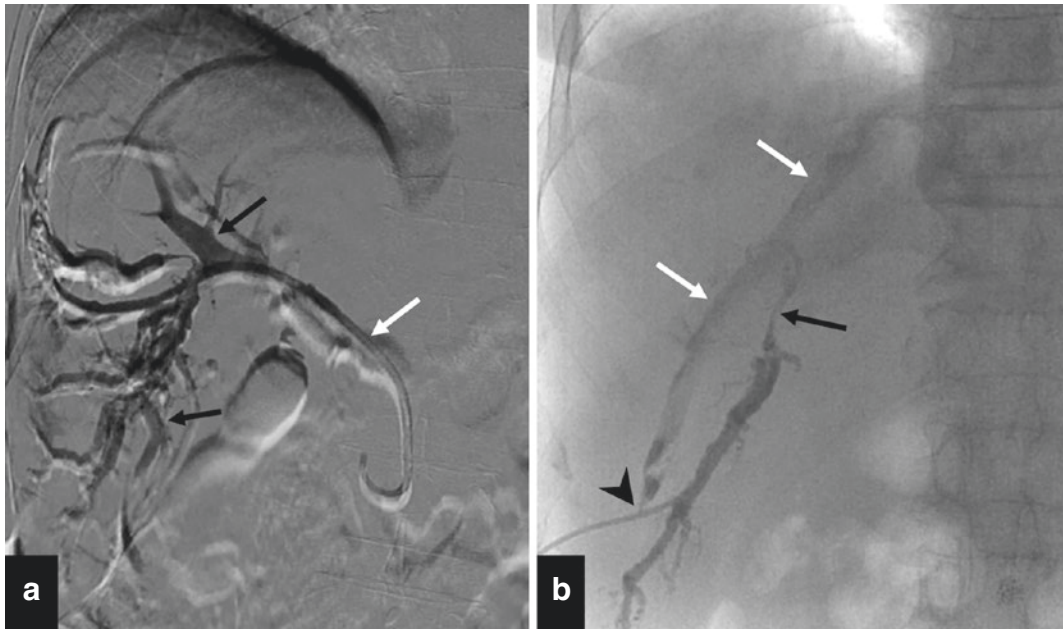

Fig. 2.10 Venous injury. (**a**) Cholangiogram shows opacification of portal vein branches (black arrows) suggesting bilio-portal fistula due to proximally displaced ring biliary catheter (white arrow). (**b**) Cholangiogram shows opacification of right hepatic vein (white arrows) due to pericatheter leak (arrowhead) around a 5F pigtail catheter which as passed through the hepatic vein

ade effect and stop bleeding as it is a low pressure system. If the communication is central, clamping may not stop the bleeding. Then, a covered stent should be placed in the biliary system or the portal vein to close the biliovenous fistula and to control bleeding [13]. If the cholangiogram does not show any vascular opacification, CT angiogram will be required to identify the source of bleeding. CT angiogram may show hepatic artery pseudoaneurysm, catheter eroding into the artery or an arterio-biliary fistula, or uncommonly, pseudoaneurysms of intercostal or superior epigastric arteries, all of which requires embolization. If the bleeding occurs after 48 h, the patient's coagulation parameters need to be evaluated along with radiological assessment, as it may be deranged, especially in patients with sepsis.

Fever—this indicates cholangitis, often due to the procedure itself and caused by manipulation of the infected biliary system, introduction of infection, and injection of more contrast. This should be treated by intravenous (admitted patient) or oral (outpatient) antibiotics and intravenous fluids. If the catheter has been capped, it should be opened and connected to a bag to drain the infected bile externally. The catheter can then be capped after a week. Although cholangiogram during this period should be avoided, it is often important to assess the position of the catheter. Partial dislodgement of the catheter results in inadequate internal drainage and thus cholangitis (Fig. 2.11a, b). Hence, with cholangiogram, any displacement will be identified and can be corrected. It may also identify cholangitic abscesses (Fig. 2.11c). USG should be done to look for any undrained biliary system, which may need drainage or any collections or bilomas which may be infected (Fig. 2.11d).

Pericatheter leak of bile—this usually indicates displacement or occlusion of the catheter (Fig. 2.12). Cholangiogram should be done to assess the position of the catheter. The catheter may be put on external drainage for a week to clear it of sludge and debris. Ascites, if present, may be a cause of pericatheter leak and should be drained. If the leak continues despite these mea-

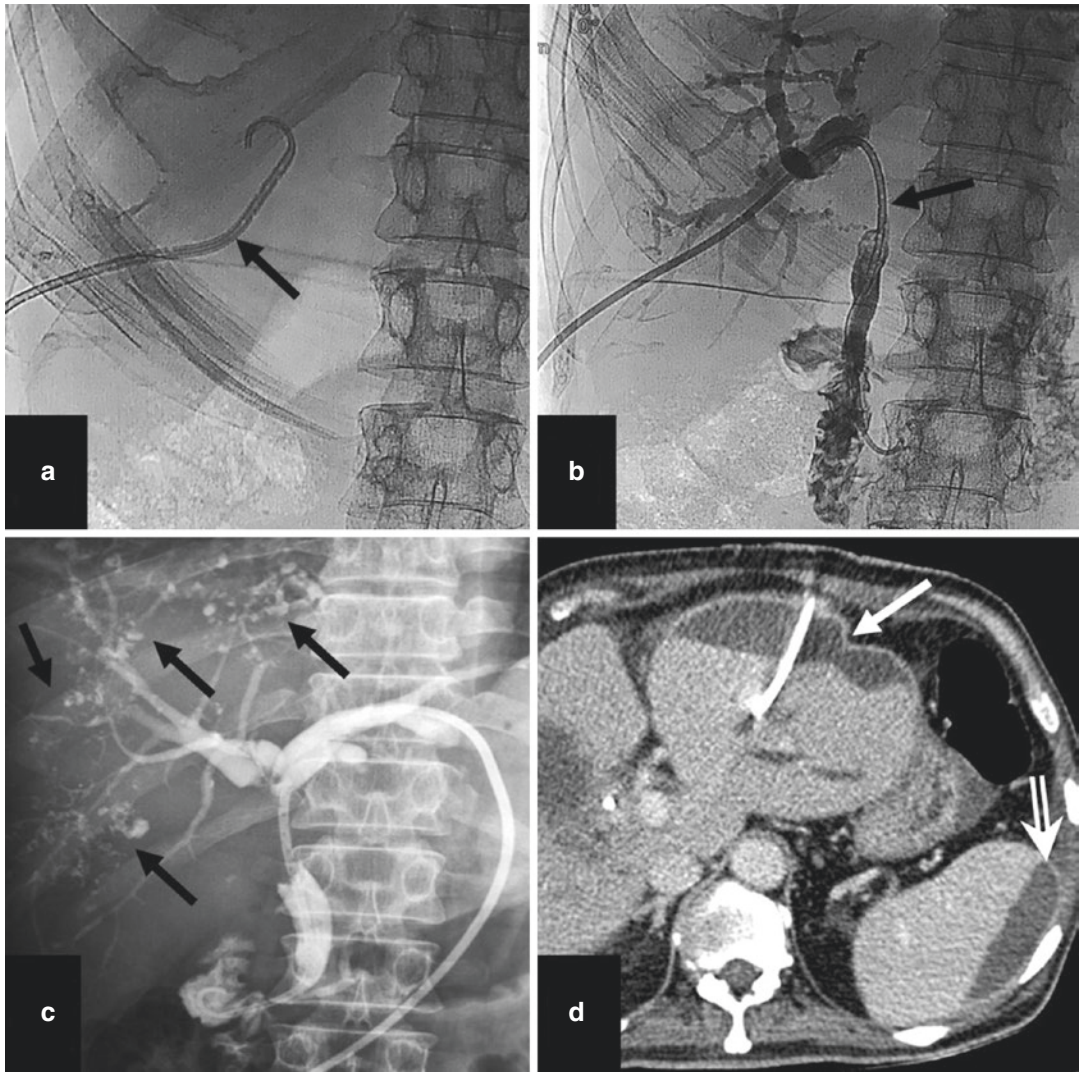

Fig. 2.11 Other complications of PTBD. (**a, b**) Displacement of ring biliary catheter. (**a**) Radiograph shows displaced ring biliary catheter (arrow). (**b**) Repositioning of the catheter to its appropriate position (arrow). (**c**) Cholangitis. Cholangiogram shows multiple small fluffy opacities (arrows) suggesting cholangitic abscesses. (**d**) Biloma. CT scan shows biloma formation in perihepatic (white arrow) and perisplenic (open arrow) regions due to pericatheter bile leak

sures, then the catheter should be upgraded, from 8F to 10F or 10F to 12F. If the leak persistently occurs with 12F, then a colostomy bag may be placed around the capped catheter to collect the leaked bile.

Catheter-related problems—since the catheter is left for a longer duration, problems like catheter displacement, complete dislodgement, and fracture are not uncommon (Figs. 2.11 and 2.12). If complete displacement occurs in the immediate period, repeat PTBD should be done. But, it is often difficult as the biliary system is likely to be decompressed. Depending on the extent of dilatation, immediate need for drainage and IR specialist's expertise, repeat PTBD may be done either immediately or later, when the dilatation is adequate. If catheter is pulled-out in a later period (after 2 weeks), the tract is usually mature.

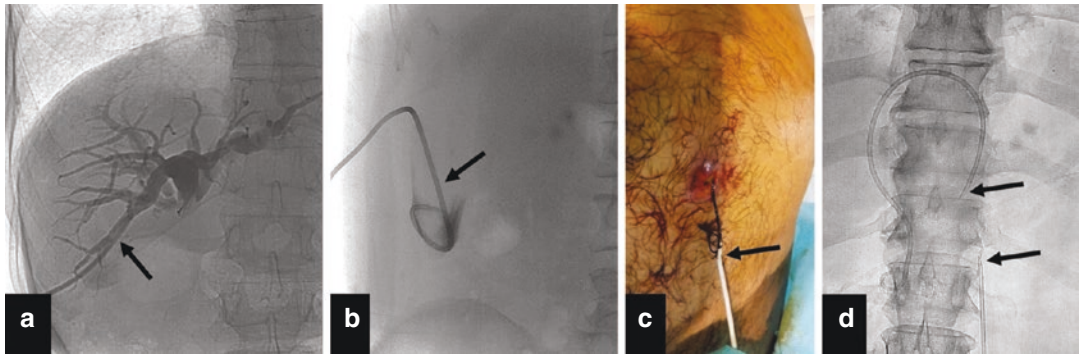

Fig. 2.12 Catheter-related complications. (**a**, **b**) Displaced catheter. After initial external drainage with pigtail catheter (arrow in **a**), patient presented 2 days later with non-draining of bile. Cholangiogram (**b**) shows a displaced catheter lying in the peritoneal cavity (arrow in **b**). (**c**, **d**) Catheter fracture. Clinical picture (**c**) and radiograph (**d**) shows the fractured ring biliary catheter with fractured ends (arrows)

Probing the tract with soft hands, using a 6F dilator/MPA catheter and J-tipped soft hydrophilic guidewire, will allow access into the biliary system, after which further steps of PTBD are followed and catheter is placed. Partial displacement of catheters should be repositioned under fluoroscopy guidance and cholangiogram (Fig. 2.11a, b). If there is a fracture of the catheter, it should be replaced. The catheter may get occluded with sludge over time and it is suggested that the catheter be exchanged every 6–8 weeks.

Pleural complications are uncommon and seen with right-sided PTBD and are in the form of pneumothorax or hemothorax. Symptomatic patients may need intercostal tube drainage.

Bile leak may occur infrequently, often due to catheter displacement, and may lead to biloma formation (Fig. 2.11d) and rarely, biliary peritonitis. Treatment is drainage of biliary collections and antibiotics.

Pancreatitis is seen in up to 1% of cases, usually due to the occlusion of the pancreatic ductal opening by the catheter or by a clot. It is usually mild, but occasionally, it may be severe.

2.4.8 Trouble Shooting

Unable to pass the initial access catheter or dilator over the soft wire—this is often seen in patients with long-standing obstruction (slow-growing tumors) or with recurrent cholangitis, where the wall of the ducts is thick and fibrous. One can try and pass a 4F catheter over the wire, which is often successful. If not, a vascular sheath (6F) could be inserted to bridge the space between the skin and the duct wall (Fig. 2.13). This prevents buckling of the catheter and allows its passage over the wire. If this also fails, a stiff dilator (usually 8F) may be pushed over the wire, with the aim of widening the puncture hole in the wall of the duct. In most cases, these measures help.

Unable to cross the stricture—this occurs mostly when the dilatation is moderate to gross and it is difficult to guide the wire through the stricture. It is better to allow external drainage and attempt after a week (Fig. 2.14). This will make the system less roomy and reduces the inflammation, which will allow the wire the pass in majority of cases. It is suggested that for all crossing, a J-tipped soft guidewire is used. A straight tip wire, although may be used, will invariably create a false tract leading to a failed attempt at internalization.

Stiff wire is across the stricture, unable to pass the catheter or dilator—this typically happens when the stricture is due to a hard fibrous mass. To pass the catheter, a vascular sheath (6F) can be used to bridge the gap, as described above (Fig. 2.13). If it is difficult to pass dilator across the stricture, there are two options. One is placing an external drainage catheter and attempting internalization later, after a week.

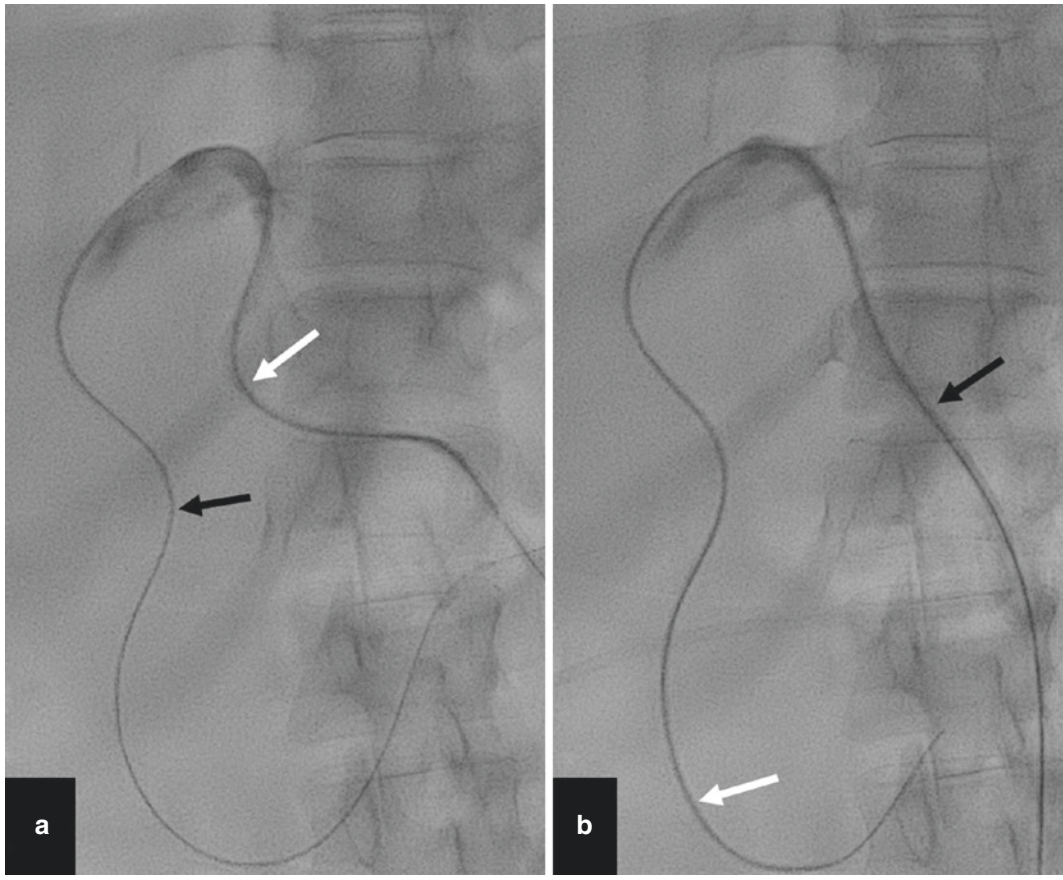

Fig. 2.13 Trouble shooting—support of sheath. (**a**) The 5F catheter buckles (white arrow) due to the resistance at stricture level (black arrow) despite the extrastiff guidewire. (**b**) Placing a vascular sheath (black arrow) provides support, preventing buckling of the catheter and allowing it to slide over the guidewire across the stricture (white arrow)

The second option is to balloon dilate the stricture, using a 4–6 mm balloon catheter (Fig. 2.15a, b). However, this increases the risk of bleeding. Either option may be chosen depending on the preference.

Unable to dilate the tract—sometimes, the duct wall is thick due to repeated cholangitis and it would be difficult to push the dilator over a stiff wire. In such cases, a smaller caliber pigtail catheter (5F or 6F) may be placed for external drainage (Fig. 2.15c). This is then exchanged for 8F catheter after a week, during which time, the duct wall undergoes pressure necrosis by the smaller caliber catheter.

2.5 Biliary Stenting

2.5.1 Indications

Biliary stenting allows internal drainage of bile into the intestine. The main indication for it is malignant biliary stricture, in the palliative setting. The causes include gallbladder cancer, cholangiocarcinoma, pancreatic cancer, metastatic lymphadenopathy, and duodenal carcinoma. Since surgical removal of the stent is challenging, it should ideally be placed in inoperable malignancies. However, it is also indicated in benign diseases not manageable by routine treatments.

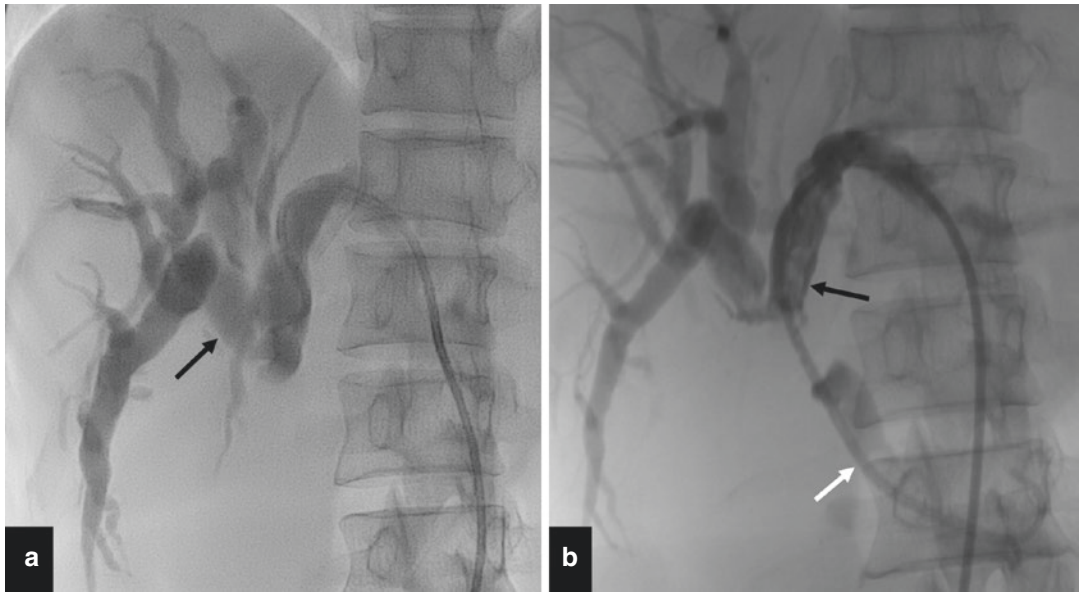

Fig. 2.14 Trouble shooting—Delayed internalization. (**a**) Cholangiogram at the time of PTBD shows gross dilatation of bile ducts (black arrow) causing failure of internalization. (**b**) Cholangiogram after a week shows partially decompressed bile ducts (black arrow) helping in internalization and placement of ring biliary catheter (white arrow)

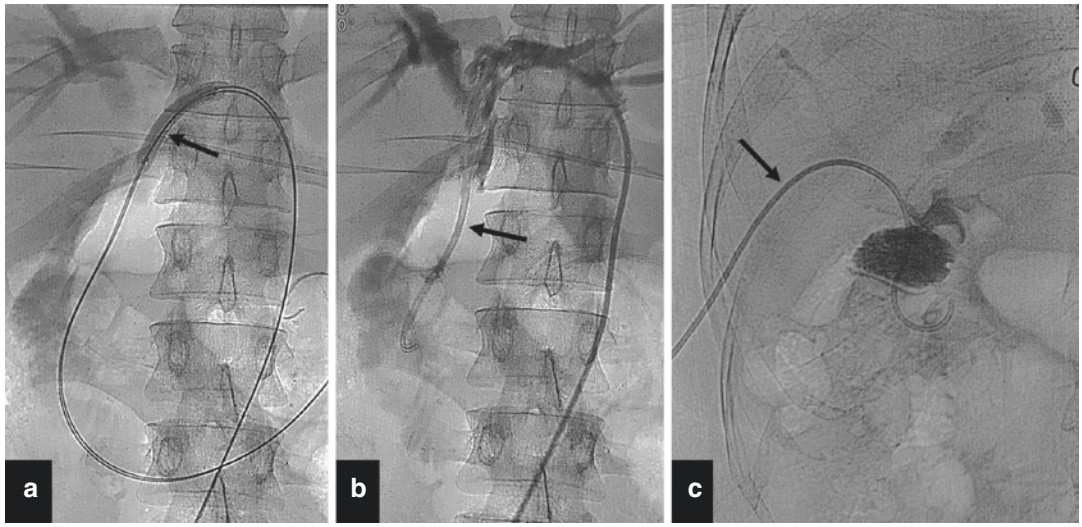

Fig. 2.15 Trouble shooting. (**a, b**) Cholangioplasty. (**a**) Balloon dilatation of the tight stricture due to cholangiocarcinoma using 6 × 40 mm balloon catheter (arrow). (**b**) Easy placement of ring biliary catheter after cholangioplasty (arrow). (**c**) Another case where a smaller caliber (5F) catheter was placed for external drainage due to difficulty in dilatation of the tract. After a week, 8F catheter placement is usually successful

2.5.2 Primary Versus Secondary Stenting

Biliary stent placement may be primary or secondary [14]. Primary stenting is when stent is placed during the initial procedure of PTBD. Secondary stenting is when the stent is placed in a subsequent session after a catheter PTBD is done. In both these settings, crossing the stricture is necessary, before a stent is placed.

Primary stenting is the preferred method in noninfected system. Secondary stenting adds to the cost in terms of additional procedure and radiation [15]. A benefit of secondary stenting is that planning is better once internalization has been done. However, secondary stenting should be done in patients presenting with cholangitis after complete resolution of the infection.

2.5.3 Procedure

Primary stenting requires admission of the patient and observation overnight after the procedure. However, for secondary stenting, admission is not necessary and may be done as a day care procedure.

Once the biliary stricture is crossed and a stiff guidewire is placed with tip in the duodenum (preferably third part for safety), biliary stent is placed (Fig. 2.16). Depending on the compatibility of the stent device, a vascular sheath (usually 6F) is placed into the biliary system over the wire. A cholangiogram through the sheath is useful to define the length of the stricture. The ideal position of the stent is to have at least 2 cm of the stent proximal and distal to the stricture. The stent device is inserted through the sheath, over the wire, and positioned such that the proximal and distal radio-opaque markers of the stent are optimal in relation to the stricture. Once in position, the stent is deployed. As soon as the stent expands, the pooled contrast proximal to the obstruction is seen to pass through the stent into the duodenum. Balloon dilatation of the stricture prior to stenting is not necessary as it does not alter complication or stent patency rates [14].

In most cases, the stent expands fully. If not, it expands over 24–48 h, once the stent reaches the body temperature. Routinely, an access catheter (5F catheter) is placed through the stent into the duodenum after removal of the sheath and kept for 48 h. The patency and expansion of the stent are rechecked after 48 h, using a vascular sheath. If it is satisfactory, then the catheter is removed. In case of partial expansion (> 60 to 70%) with free flow of contrast no balloon dilatation may be required. However, for <50% expansion or no free flow of contrast through the stent, balloon dilatation may be done using an undersized balloon catheter (Fig. 2.17). After dilatation, an access catheter must be left in situ and again reassessed after 48 h. In most cases, this is sufficient to expand the stent.

2.5.4 Types of Stents

Two common types of stents used are uncovered and covered [16].

The most commonly used stent is the uncovered self-expandable metallic stent (SEMS). The diameter of the stent is usually 10 mm for CBD and 8 mm for hepatic ducts. The length of the stent varies with the length of the stricture. One has to place the ends of the stent, 2 cm proximal and 2 cm distal to the ends of the stricture. If the stricture is long, two overlapping stents may be necessary.

Uncovered stents are usually preferred as they do not cause occlusion of the undrained ducts, cystic duct, and pancreatic duct [16]. Further, there is a very low chance of migration and the stent costs less than a covered stent. However, there is a higher incidence of tumor ingrowth, occluding the stent. On the other hand, covered stents improve stent patency by preventing stent ingrowth [17]. However, there are higher risks of cholangitis, cholecystitis, and pancreatitis due to occlusion of the ducts. The risk of migration and occlusion by sludge is also higher [18]. A modified covered stent with proximal and distal bare ends of about 2 cm each improves anchoring and helps in preventing migration [18]. Studies have, however, shown no significant difference in long-term patency and survival between the two stent types.

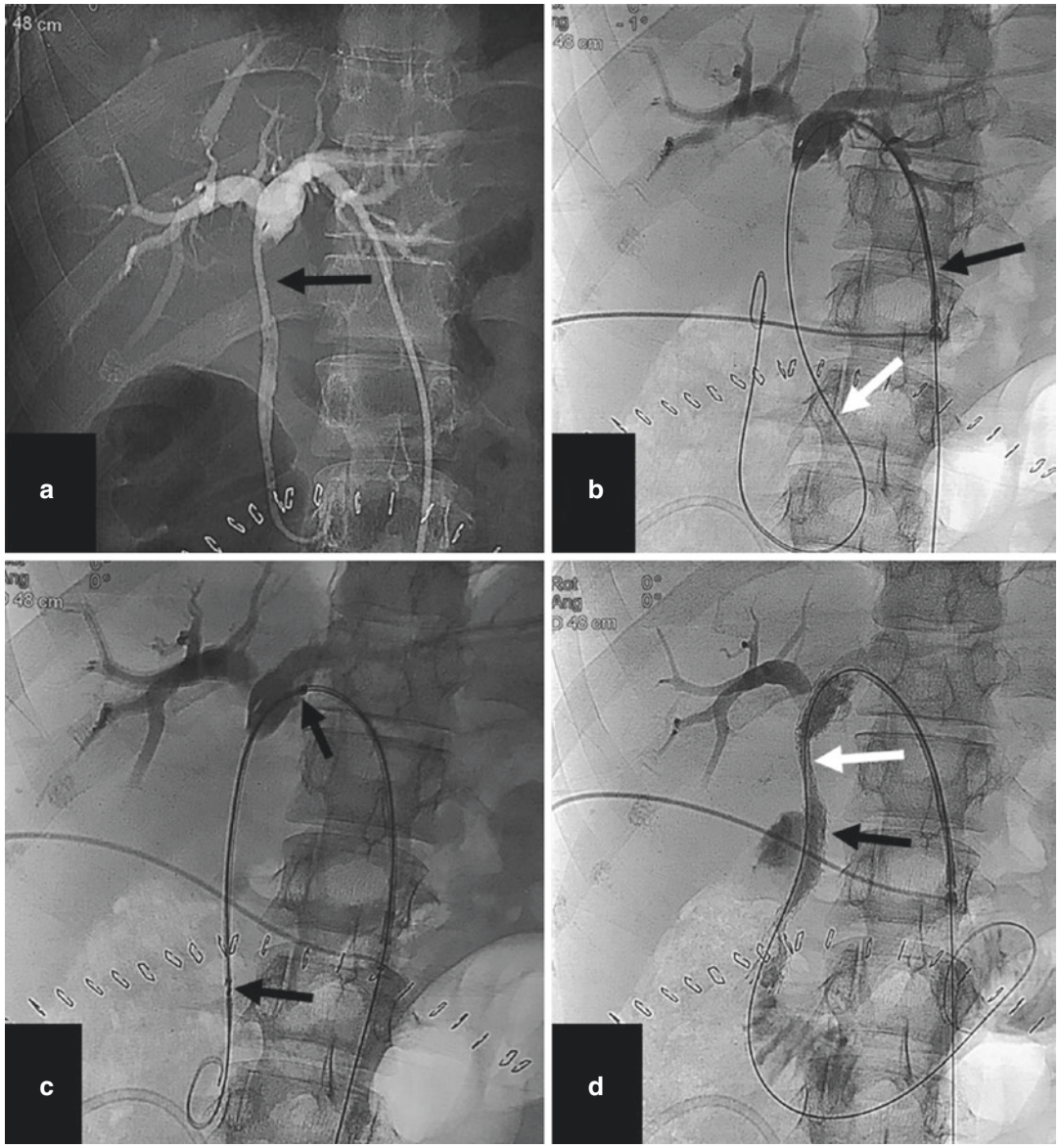

Fig. 2.16 Unilateral secondary biliary stenting. (**a**) Cholangiogram showing ring biliary catheter after internalization. (**b**) Placement of a vascular sheath (black arrow) over an extrastiff guidewire (white arrow). (**c**) Appropriate positioning of self-expandable metallic stent with the help of the platinum end markers (arrows). (**d**) Fully deployed stent (black arrow) with distal flow of contrast. The narrowing of the stent at the site of stricture (white arrow) usually expands over 24–48 h

2.5.5 Suprapapillary Versus Transpapillary Stent

For mid and distal CBD strictures, it is still not clear if the lower end of the stent should remain proximal to the ampulla (suprapapillary) or should cross the ampulla (transpapillary) (Fig. 2.18) [19]. Suprapapillary placement may cause dysfunction of the sphincter of Oddi (SOD) resulting in its spasm and reduced clearance of bile across it. Transpapillary stenting increases

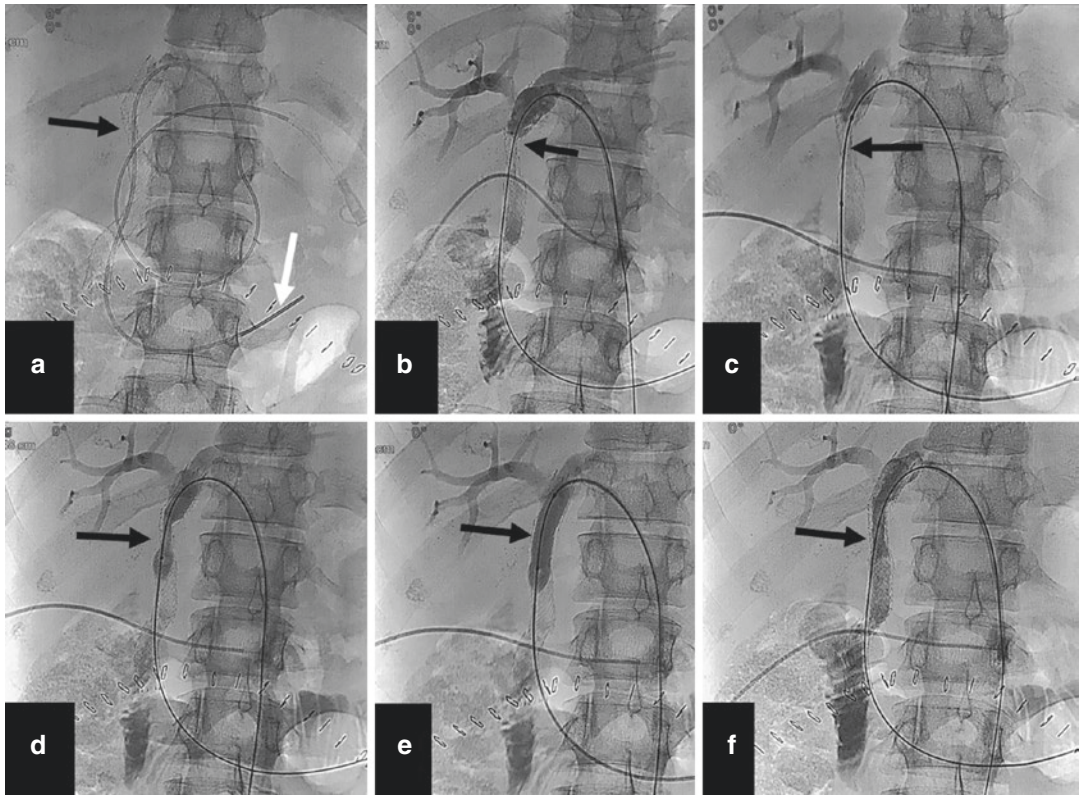

Fig. 2.17 Post-stenting balloon dilatation. (**a**) Radiograph shows fully expanded stent (black arrow) with 5F access catheter (white arrow). (**b**) Cholangiogram obtained using a vascular sheath placed over a wire shows restricted flow of contrast at the site of the tumor (arrow) with stasis. (**c**) Position of 10 × 40 mm balloon catheter across the obstruction with the help of radio-opaque markers (arrow). (**d**) On inflation of the balloon catheter, waist (arrow) is seen. (**e**) Fully expanded balloon catheter (arrow). (**f**) Post dilatation cholangiogram shows free distal flow of contrast across the tumor (arrow)

the risk of reflux of duodenal contents into the biliary system and thus cholangitis. It is suggested that transpapillary stenting should be done for distal bile duct strictures which show angulation at its junction with normal duct [19]. In a comparative study, it was shown that supra-papillary stent was associated with higher incidence of tumor growth, but lower incidence of pancreatitis and occlusion by sludge [20]. However, there was no difference in stent patency or patient survival between the groups.

2.5.6 Y or T stents

In cases of hilar obstruction, unilateral stenting is often sufficient for improving patient's symptoms due to biliary obstruction [21]. However, frequently, bilateral stenting may be necessary, especially if the serum bilirubin is not dropping or if the undrained system is infected [18]. This can be done by two methods [22].

Y stent—here, the biliary system is accessed through both sides (right and left) and wires are passed across the stricture into the duodenum (Fig. 2.19). Subsequently, two SEMS are deployed simultaneously to drain both biliary systems. This procedure requires additional drainage of the opposite biliary system.

T stent—here, the biliary system is accessed percutaneously through one side (right or left) (Fig. 2.20). Then, through this side, two soft hydrophilic guidewires are passed crossing the stricture, one to the bile ducts of the contralateral

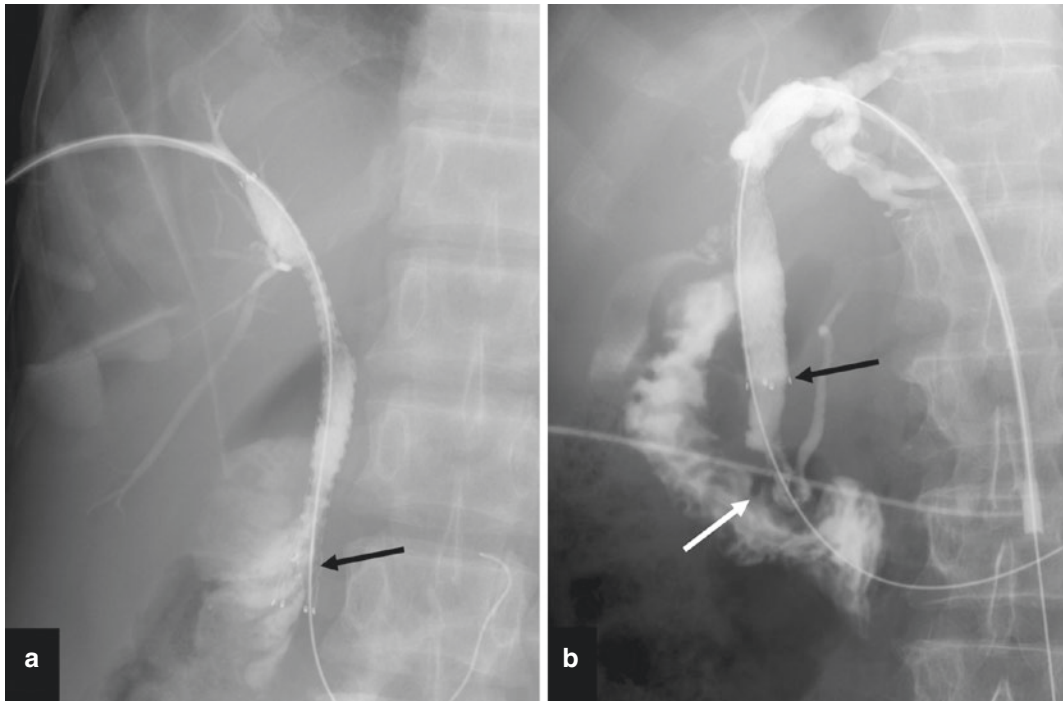

Fig. 2.18 Stent positioning. (**a**) Transpapillary (arrow) biliary stent placement. (**b**) Suprapapillary placement of stent with the lower end of the stent (black arrow) above the ampulla (white arrow)

side and the other into the distal CBD or duodenum. After exchanging these soft wires for stiff guidewires, SEMS (preferably 8 mm diameter) are passed over each wire and deployed.

2.6 Additional Procedures Through PTBD Route

2.6.1 Brush Cytology/Forceps Biopsy

Once the biliary system is accessed percutaneously, the same route may be used to obtain samples of tissue responsible for the obstruction [23]. The devices for cytology or biopsy are not over the wire (OTW) and hence a longer vascular sheath, which can reach the point of obstruction, is necessary. Once the tip of the sheath is at the tumor, the cytology brush or biopsy forceps is introduced through the sheath to obtain samples from the lesion. The sensitivity of brush cytology variably ranges from 40% to 75% [24]. The use of forceps biopsy or combination of cytology and biopsy improves the sensitivity of the sampling. This is especially useful in cases of biliary strictures where the mass is small and a standard method of sampling is not possible.

The initial procedure is similar to PTBD [25]. Once, the wire is across the stricture, a longer vascular sheath (6–8F) is placed with its tip just across the stricture (Fig. 2.21). Then the cytology brush or the biopsy forceps is passed through the sheath to enter the stricture. Then the brush is scraped over the stricture a few times, under fluoroscopy, and removed. The sample is then either spread on the slide or immersed in a bottle with fixative for pathological evaluation. If a biopsy forcep is used, samples of tissue are obtained from the stricture site and transferred to a bottle with fixative.

2.6.2 Endobiliary Radiofrequency Ablation

The PTBD tract may also be used to ablate the tumors causing biliary obstruction. Radiofrequency ablation (RFA) is one such technique. During

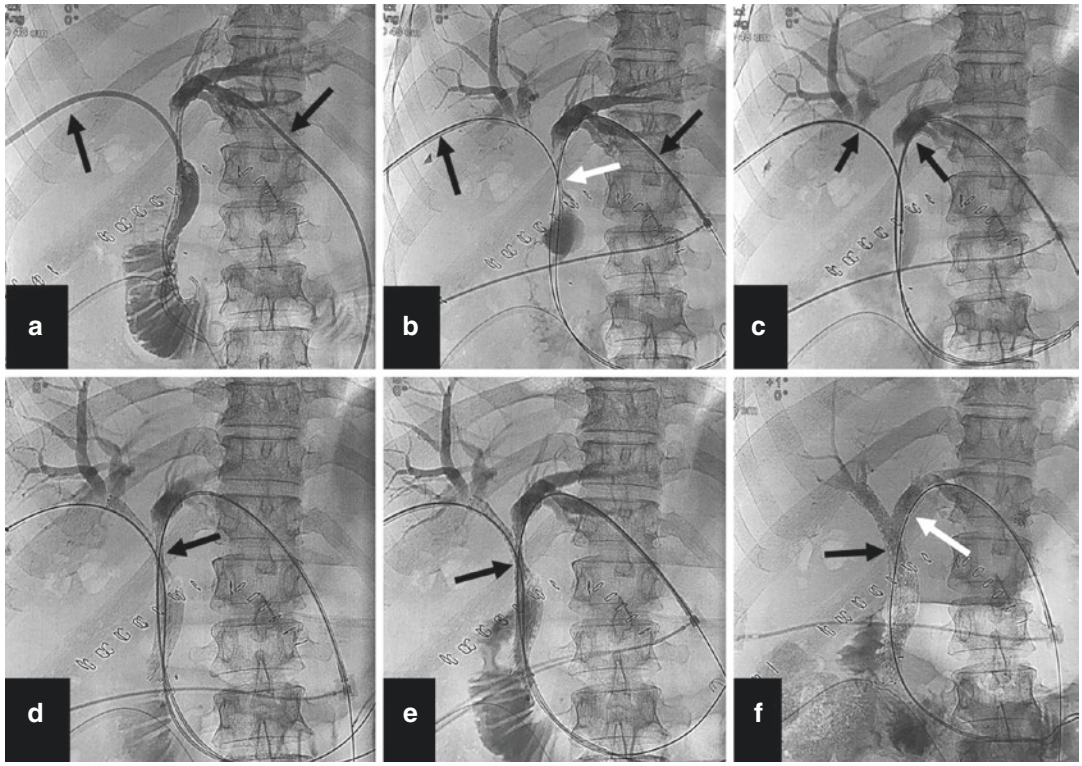

Fig. 2.19 Bilateral secondary stenting (Y stent). (**a**) Bilateral ring biliary catheters placed after internalization. (**b**) Cholangiograms from both sides after placement of the sheaths (black arrows) over extrastiff guidewires to define the stricture (white arrow). (**c**) Simultaneous positioning of self-expandable metallic stents (arrows; 8 × 100 mm) with the help of end markers. (**d**) Fully deployed bilateral stents across the stricture (arrow). (**e**) Cholangiogram from the left side shows partial expansion of the stents at the site of stricture (arrow). (**f**) Cholangiogram obtained from the left side (white arrow) after 2 days shows complete expansion of both stents at the site of stricture (black arrow) with free distal flow of contrast

PTBD, once the stiff wire has been placed across the stricture, the flexible RF probe is passed over the wire, through a sheath and positioned at the level of the tumor (Fig. 2.22) [26]. By applying adequate RF energy, the tumor can be ablated, without causing significant complications. After RFA, SEMS is usually placed. The same technique is frequently used to recanalize an occluded SEMS due to tumor ingrowth [27]. Post RFA, a balloon catheter is used to sweep down the debris into the duodenum. RFA has shown to improve the patency of the stents placed in palliative setting.

2.6.3 Endobiliary Brachytherapy

Similar to RFA, malignant biliary stricture may be treated with radiotherapy through the PTBD tract [28, 29]. This is usually indicated in patients with inoperable malignant biliary strictures due to locally advanced disease. It is better than external beam radiotherapy as higher dose of radiation can be given to a defined target area, without much affecting the surrounding normal tissues. Since around 1 cm of tissue is irradiated, it may improve stent patency.

Iridium-192 is used as the radiation source [29]. Once a catheter, 10F size, is placed across the stricture, the Iridium-192 pellets with applicator are inserted through the catheter and positioned across the stricture with 1–2 cm proximal and distal margins. High dose rate is commonly delivered. Post-procedure, the applicator is removed and the ring biliary catheter is left in situ.

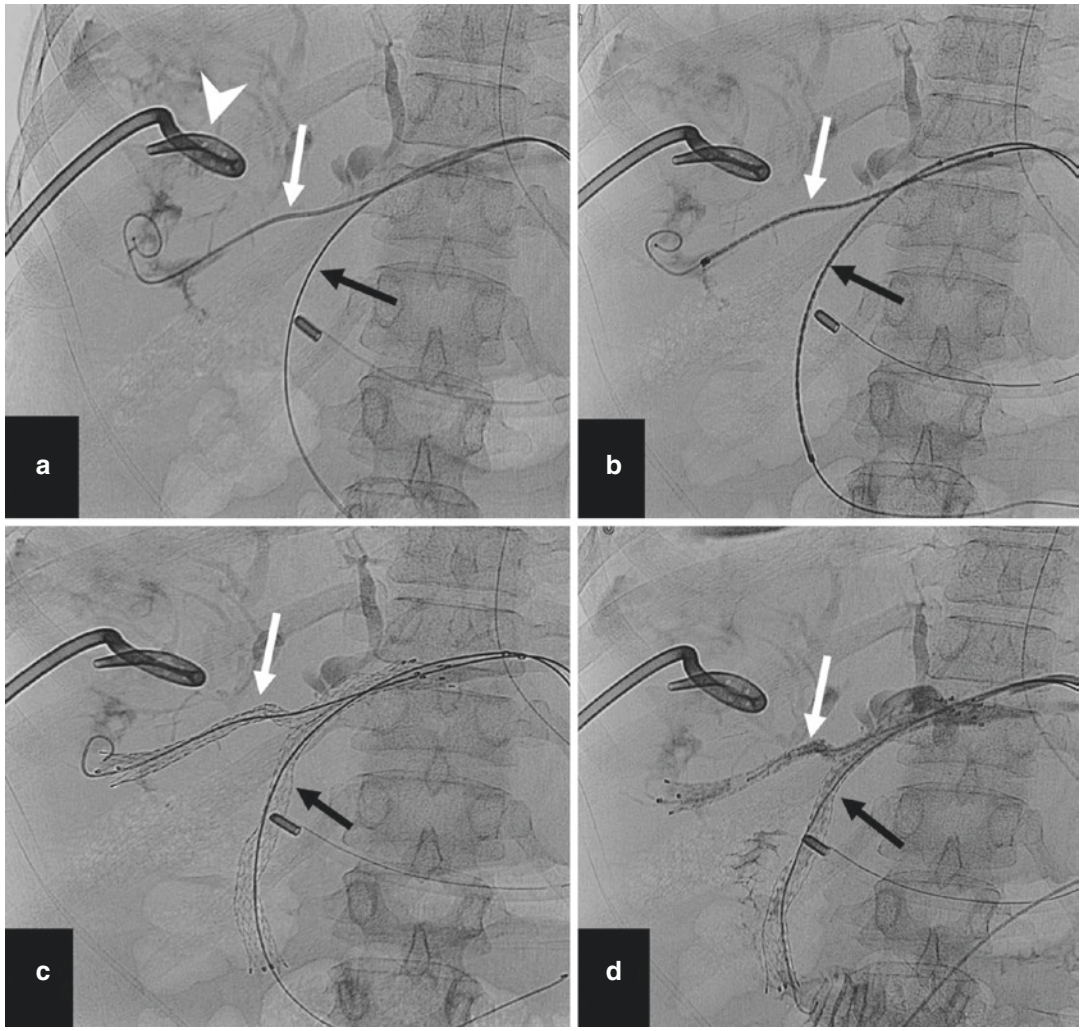

Fig. 2.20 T-stenting. 40-year-old female with gallbladder cancer-causing hilar obstruction and right lobar cholangitic abscess. (**a**) Fluoroscopic spot image shows two guidewires, one passing from left lobe to duodenum (black arrow) and the other from left lobe duct to right lobe duct (white arrow) along with a pigtail catheter in the abscess (arrowhead). (**b**) Positioning of the stents in T morphology, one from the left duct to the right duct (white arrow; 8 × 80 mm) and other from the left duct to duodenum (black arrow; 8 × 100 mm). (**c**) Fully deployed stents in T morphology (black and white arrows). (**d**) Cholangiogram shows free flow of contrast in both stents (black and white arrows)

2.7 PTBD for Benign Biliary Obstruction

Benign biliary strictures are frequently an indication for PTBD [30]. Although, in many cases, EBD is attempted, there are few specific situations where PTBD is the treatment of choice. Procedure is mostly similar to that described above, except for some minor variations and precautions. The follow-up protocol is different.

2.7.1 Clinical Presentation

Majority of these patients present with recurrent episodes of fever with chills due to recur-

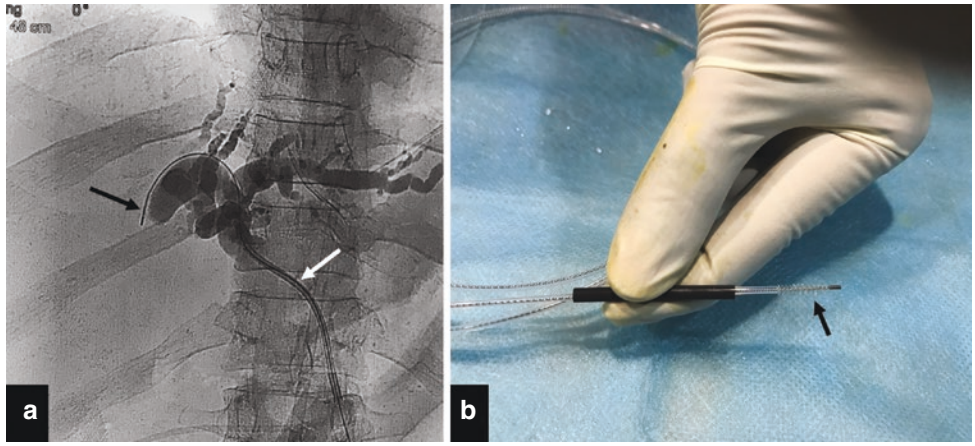

Fig. 2.21 Brush cytology. (**a**) Cytology brush (black arrow) positioned right at the point of stricture after pulling back the sheath (white arrow) to take sample. (**b**) Brush cytology device with thin bristles near its tip (arrow)

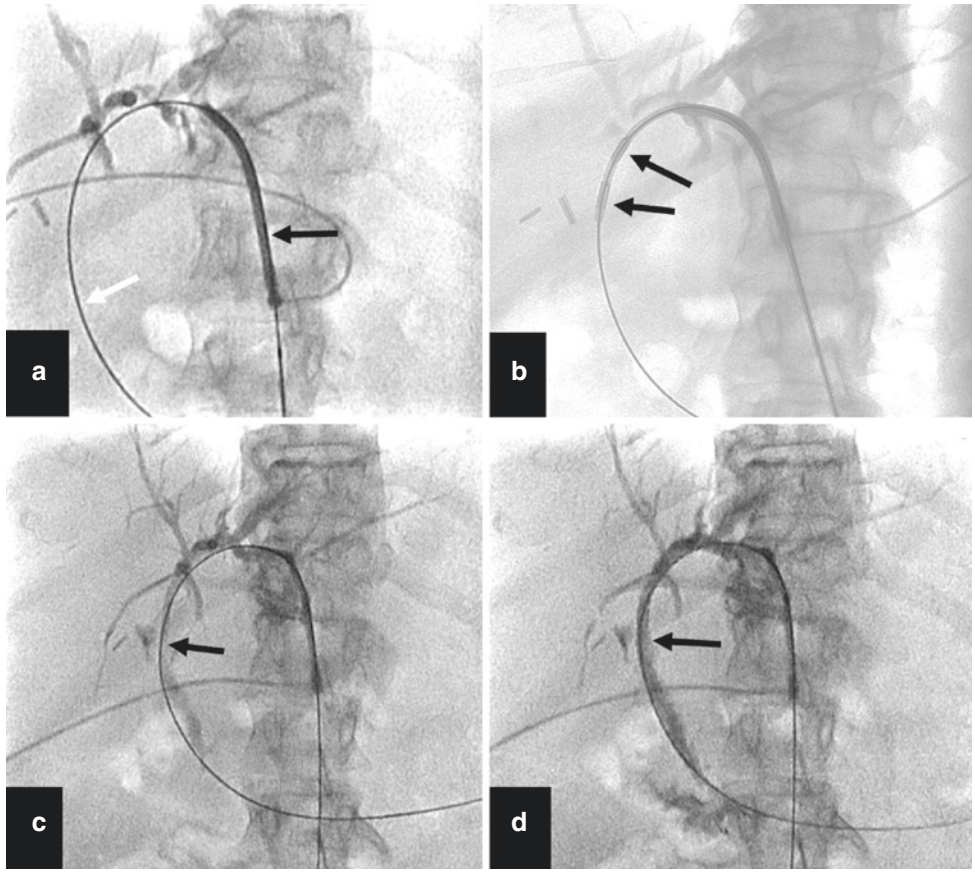

Fig. 2.22 Biliary radiofrequency ablation (RFA). (**a**) Cholangiogram obtained by a sheath (black arrow) placed over a wire (white arrow) shows obstruction of common hepatic duct. (**b**) Positioning of the RFA probe (arrows) over the wire at the site of tumor. (**c**) Cholangiogram after RFA shows flow of contrast across the stricture (arrow). (**d**) Placement of biliary stent after RFA (arrow). (Images courtesy: Dr. Amar Mukund, Additional Professor, Institute of Liver and Biliary Sciences, New Delhi)

rent cholangitis [30]. Uncommonly, they may present with jaundice or pain abdomen. Occasionally, the patients may be asymptomatic and liver function tests show abnormally elevated alkaline phosphatase. Chronic obstruction may result in secondary biliary cirrhosis and patient may present with features of portal hypertension like hematemesis or ascites.

2.7.2 Indications

Two most common indications are stricture of a bilio-enteric anastomosis (commonly hepaticojejunostomy) and post-liver transplant biliary stricture (Figs. 2.23 and 2.24). Other indications include CBD stones (Fig. 2.25), chronic pancreatitis, and infective/inflammatory strictures (recurrent pyogenic cholangitis, Immunoglobulin G4 cholangitis, ischemic cholangitis), when EBD is difficult or failed.

2.7.3 Special Considerations for PTBD

The steps of the PTBD procedure is similar to that described previously for malignant biliary obstruction. However, there are some special considerations. In obstruction due to benign strictures, the lesion gradually narrows the lumen and hence the dilatation of IHBD is mild in majority of cases. Hence, the absence of adequate dilatation should not be a reason to not do PTBD. Accordingly, the hardware for puncturing mildly dilated ducts are required (Fig. 2.2). For the same reason, the serum bilirubin is not much elevated and the patient is often not icteric. Elevation of serum alkaline phosphatase is a more consistent feature. Further, due to slow progression and recurrent episodes of cholangitis, the walls of bile ducts are frequently thick with periductal fibrosis. Hence, small caliber catheters, particularly 4F catheter, is useful to gain access into the system after the initial puncture. Crossing the obstruction is tougher than in malignant cases. The obstruction is mostly a fibrotic stricture and penetrating in with a wire is difficult compared to a softer tumor. The flow of contrast across the stricture to opacify the distal segments during the initial cholangiogram is a positive sign. The catheters which are inserted have to be in place for long duration to allow the stricture to remain patent after the catheter's removal. Catheter maintenance is often challenging in such conditions.

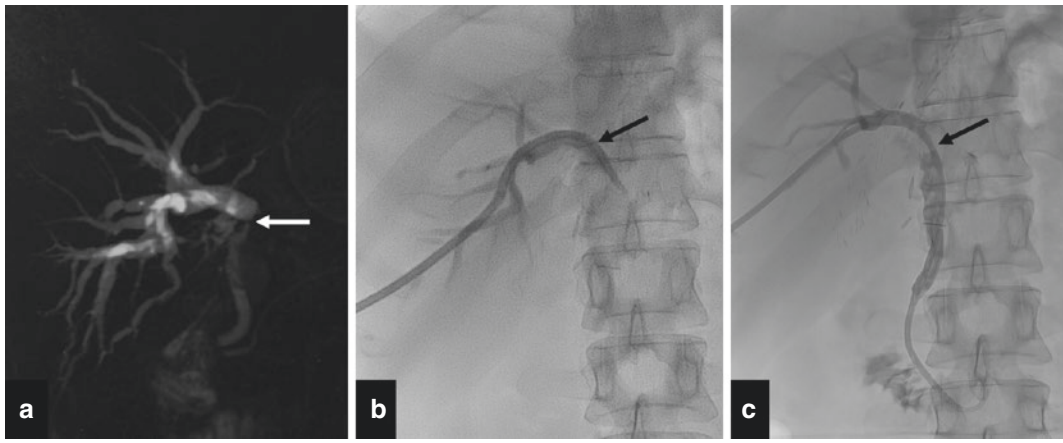

Fig. 2.23 Post-liver transplantation biliary stricture. (**a**) MRCP image shows tight anastomotic bile duct stricture (arrow) in a case of right lobe living donor liver transplantation. Endoscopic drainage failed. (**b**) Right PTBD with external drainage. (**c**) Ring biliary catheter (arrow) placement across the stricture after balloon dilatation

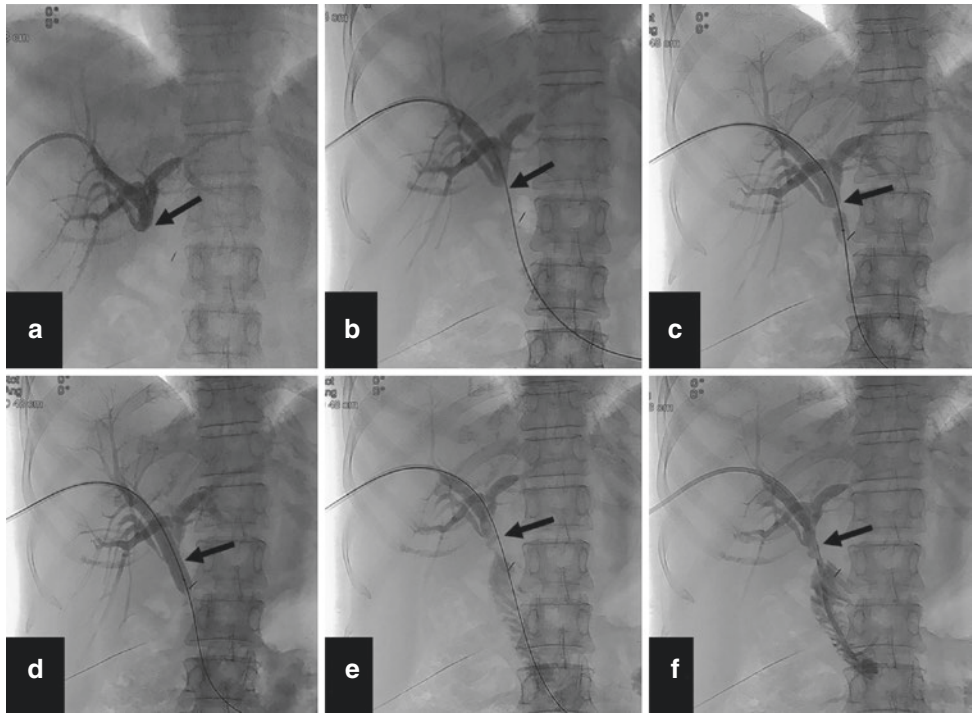

Fig. 2.24 Benign biliary stricture. (**a**) Initial cholangiogram shows complete stricture at the bilio-enteric anastomotic site (arrow). (**b**) Passage of guidewire across the stricture (arrow). (**c**) Dilatation using balloon catheter (10 × 40 mm) shows waist at the site of stricture (arrow). (**d**) Fully inflated balloon (arrow). (**e**) Cholangiogram after balloon dilatation shows free flow of contrast into the jejunum. (**f**) Final placement of 8.3F ring biliary catheter (arrow) across the stricture

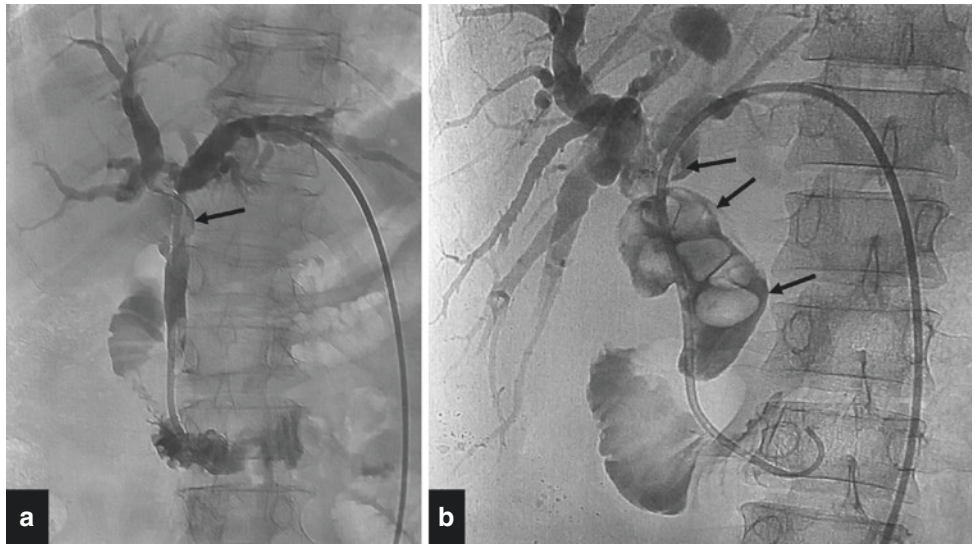

Fig. 2.25 PTBD for stone disease. (**a**) Left PTBD in a case of Mirrizzi's syndrome caused by a calculus seen as a filling defect (arrow) in the neck of gallbladder. (**b**) Left PTBD in a case of choledocholithiasis (arrows) with choledochal cyst. PTBD was done in both patients as endoscopic drainage was not possible due to associated cardiac comorbidities

2.7.4 Modifications

There are a few modified steps which are necessary or may be performed with PTBD when it is done for benign strictures.

Balloon dilatation (cholangioplasty) of the strictures is an important step to open up the strictures (Figs. 2.23 and 2.24). Once the stricture is crossed with a soft guidewire, it is exchanged for a stiff guidewire. Then, a vascular sheath (6F) is placed into the biliary system over the wire. Through the sheath, a balloon catheter, 8 or 10 mm (15–20% oversized compared to the size of the duct), is inserted [31]. With the markers of the balloon positioned appropriately, the balloon is dilated with an inflation device and kept for 3–5 min. A waist is usually seen, which has to be fully dilated. After this, the balloon is deflated and inflated again, to check for waist formation. Usually, after full inflation, waist is not seen on repeat dilatation of the balloon. Later, the balloon catheter is removed along with the sheath and an 8–10F ring biliary catheter is placed. For short segment strictures, short term and long-term patency rates for balloon dilatation are 90% and 74%, respectively [1, 32]. Lower patency is seen when the strictures are long segment and multiple.

Serial upgradation of catheters is a better option for the successful treatment of benign biliary strictures (Fig. 2.26) [33]. Even though the stricture is dilated with a 10 mm balloon catheter, it gradually heals and remodels around the catheter which is inserted. Once a smaller caliber ring biliary catheter (usually 8F) is placed, it is upgraded in a staged manner, every 4 weeks, to 10F, 12F, and then to 16 or 18F. Once the final size is reached, it should be kept for 3–6 months to allow the stricture to completely heal around the catheter and maintain patent [33]. After the end of the treatment, patency of the stricture may be evaluated by a cholangiogram using a vascular sheath, after removal of the catheter over a wire. Prompt distal flow of contrast across the stricture and absence or little proximal stasis suggest successful treatment. This protocol has good long-term results, with failure or recurrence rates in the range of 12–44% [34, 35].

Cutting balloon and high-pressure balloon catheters have also been used in the dilatation of hard fibrotic strictures with reasonable success rates [36, 37]. Cutting balloon catheter, as the name indicates, has thin metallic blades on the surface of the balloon, which creates cuts in the fibrotic wall and opens up the stricture on the dilatation of the balloon. Similarly, high-pressure balloon catheters endure high inflation pressure without bursting of the balloon. Hence, they are useful in the opening up of tight strictures.

Stents have also been used in the management of benign biliary strictures [38, 39]. Although it is not usually advisable, in chronic and inoperable cases, this may be the only practical option. Typically, retrievable or spontaneously migrating covered stents are preferred, although it is technically challenging to remove them. Non-retrievable stents usually get occluded by sludge and debris in 8–12 months. Compared to balloon dilatation, the stent placement has higher 3-year patency rates (53% versus 85%) [39]. Currently, there is ongoing research on the use of biodegradable stents for benign biliary strictures and it has shown promising results, with a stricture recurrence rate of about 30% at 3 years [40].

Stone removal should be attempted when there are calculi obstructing the biliary system or when there are secondary calculi proximal to a benign stricture (Fig. 2.27) [41, 42]. It is important to remember that only handful of stones may be successfully removed by percutaneous interventions. If there are too many calculi, surgery is the better option after PTBD for their removal. Removal of the stones is done with the use of a balloon catheter (6–10 mm). Since most are secondary calculi, majority of them are not calcified and are soft stones which could be macerated by balloon catheters. Access of the biliary system should be planned carefully as it should be proximal to the site of the location of the stones [1, 5]. Cholangiogram will confirm the location and number of filling defects. After insertion of a stiff guidewire across the obstruction and a vascular sheath proximally, the balloon catheter (preferably compliant) is inserted to reach proximal to the calculi. Then it is partially inflated and pushed over the wire to push the calculi into the duode-

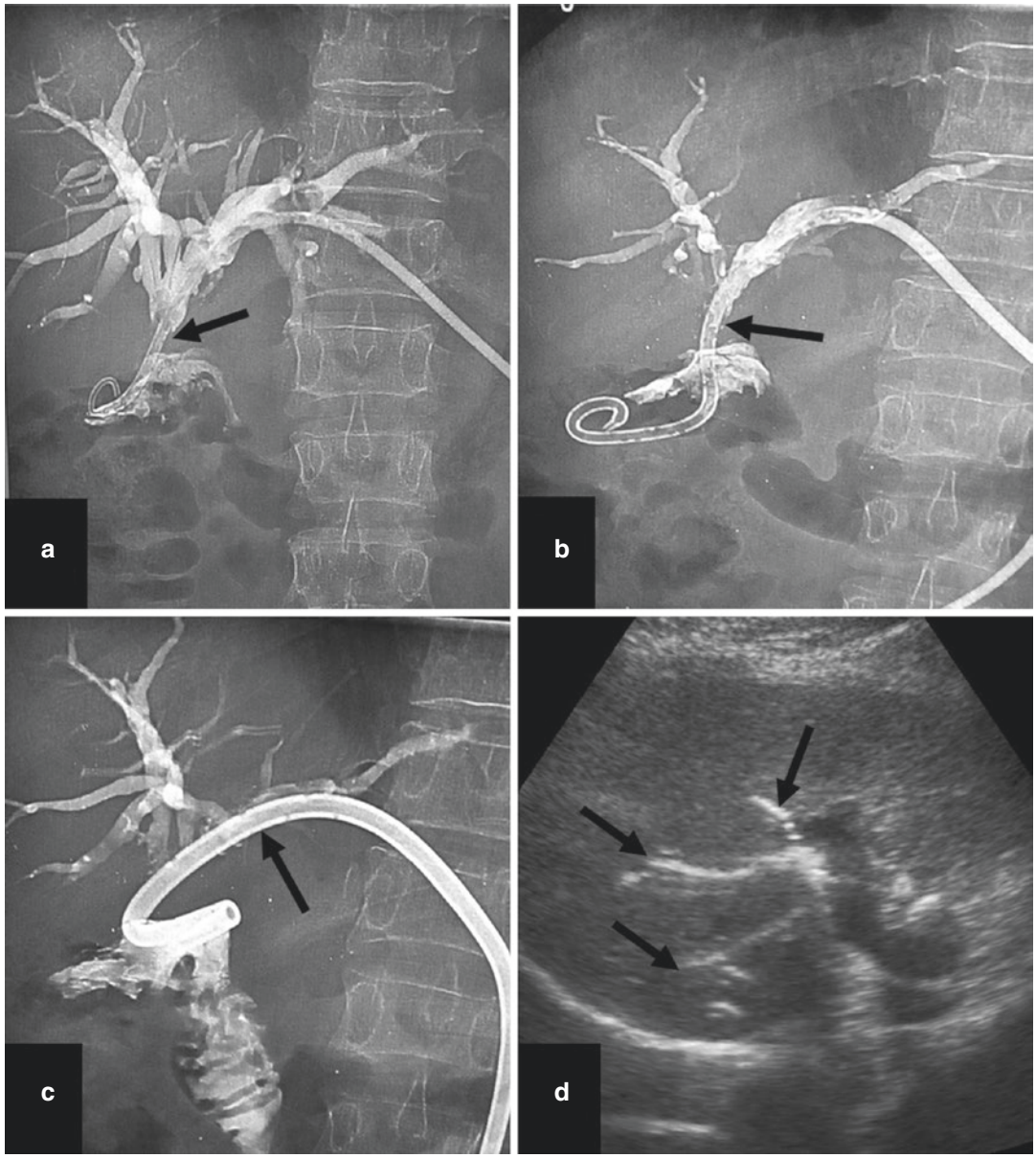

Fig. 2.26 Serial upgradation of catheter. (**a**) 10F ring biliary catheter (arrow) across the bilio-enteric anastomotic stricture after 4 weeks of placement of 8.3F catheter. (**b**) 12F catheter (arrow) placed after 4 weeks. (**c**) 16F catheter (arrow) placed after another 4 weeks. This catheter is placed for a minimum of 3 months. (**d**) Ultrasonography after 3 months of removal of 16F catheter shows pneumobilia (arrows) suggesting patency of the anastomosis

num or bowel loops (Fig. 2.27c, d). Multiple such attempts may be necessary to clear larger or multiple calculi. However, impacted stones may pose a bigger challenge and may require a cholangioscope to fragment them with holmium laser. Success rates of percutaneous stone extraction are about 90% for common bile duct calculi and 60% for intrahepatic bile duct stones [43].

Duct localization is an important procedure performed for benign biliary strictures involving the hepatic hilum. Hilar strictures, mostly after a cholecystectomy, pose a problem for the surgeon,

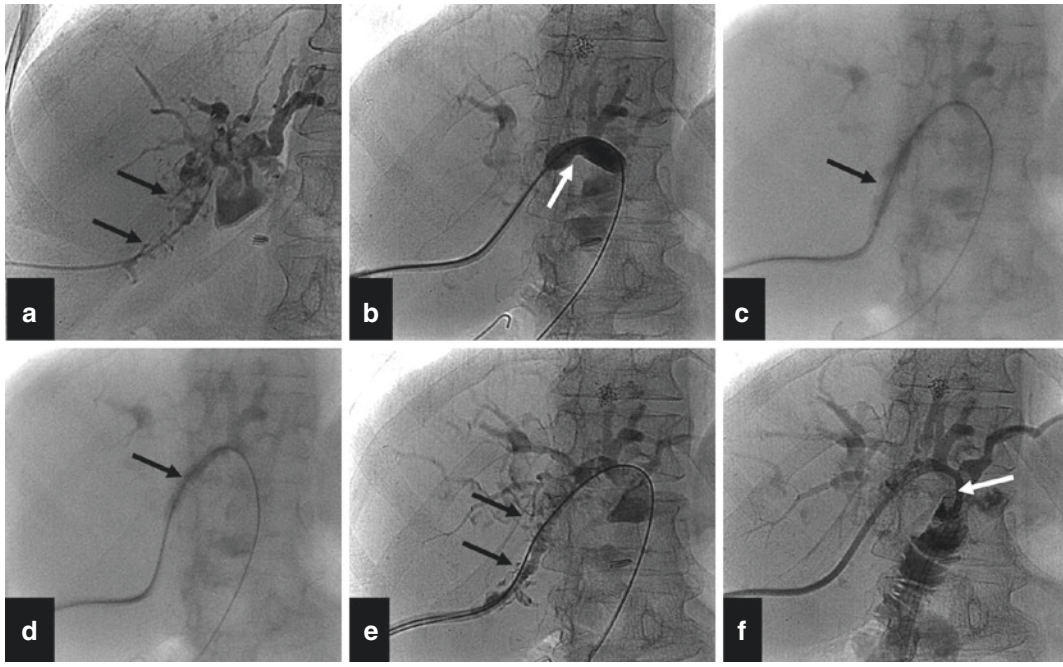

Fig. 2.27 Stone extraction in a case of bilio-enteric anastomotic stricture. (**a**) Initial cholangiogram shows multiple filling defects (arrow) within the bile ducts suggestive of calculi. (**b**) Balloon dilatation of the anastomotic stricture using balloon catheter (10 × 40 mm). (**c**, **d**) Pushing of the calculi into the jejunum by sweeping the partially distended balloon catheter over the wire from the bile ducts into the duodenum (arrow). (**e**) Post multiple balloon sweeps, cholangiogram shows reduction in the intrabiliary filling defects (arrows). The residual calculi were removed in the second session. (**f**) Placement of ring biliary catheter across the anastomotic stricture (arrow)

as they are frequently difficult to identify due to extensive surrounding adhesions and fibrosis. Hence, prior to a definitive bilio-enteric anastomotic surgery, PTBD (unilateral or bilateral, often the latter) is done with catheters placed just proximal to the stricture (Fig. 2.28). This helps the surgeon as he can palpate the catheter at surgery and thus identify the ducts. The procedure is similar to any PTBD.

2.8 PTBD for Bile Leaks

Bile leak occurs as a complication of many biliary procedures, commonly, cholecystectomy, pancreatic surgery, hepaticojejunostomy, and hepatectomies, with an incidence ranging from 0.5% to 20% depending on the type of surgery [44, 45]. Leak may occur either due to bile duct injury or anastomotic site leak. Bile leak leads to formation of collections (bilomas) which may get infected. Also, constant leak of bile from the surgical site prevents internal healing. Although endoscopic drainage is the initial option, in cases where there is complete separation of proximal and distal ends (which leads to difficult cannulation of proximal segments), bile duct ligation, altered anatomy (hepaticojejunostomy) or disruption of an aberrant duct, EBD may not be possible or successful [46]. PTBD in such cases is the treatment of choice. It helps in diverting the bile to an external collector bag and thus allows healing of the surgical site internally. However, imaging with USG, CT scan, MRI, and/or cholescintigraphy should be done to look for collections, duct caliber, and level of bile leak prior to performing PTBD.

2.8.1 Indications

Any hepatobiliary or pancreatic surgery with suspected or confirmed bile leak, when EBD is not possible or contraindicated.

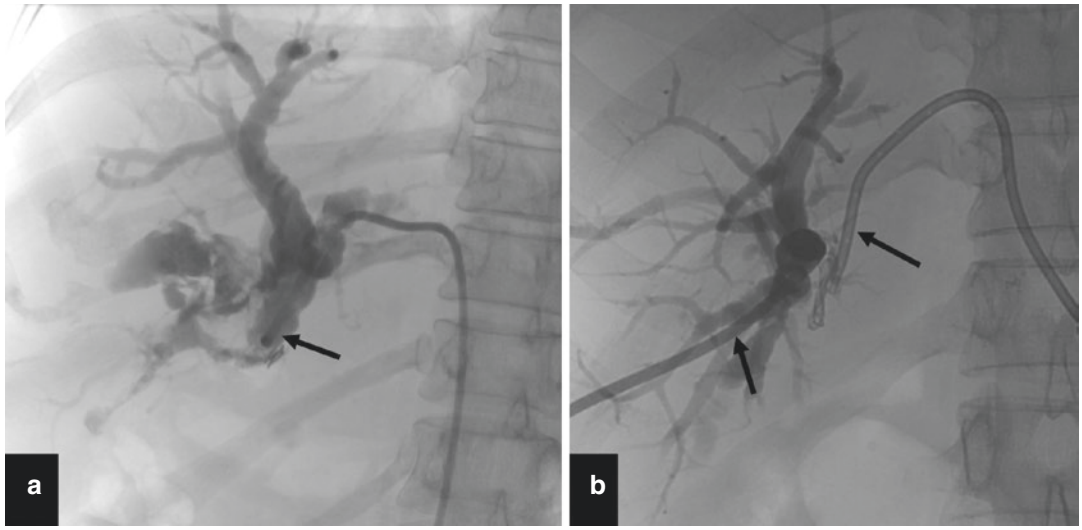

Fig. 2.28 Preoperative PTBD for duct localization in benign biliary strictures. (**a**) Left PTBD with external drainage catheter (arrow) in a case of benign biliary stricture with patent primary confluence. (**b**) Bilateral PTBD with external drainage catheters in a case of benign biliary stricture involving hepatic hilum

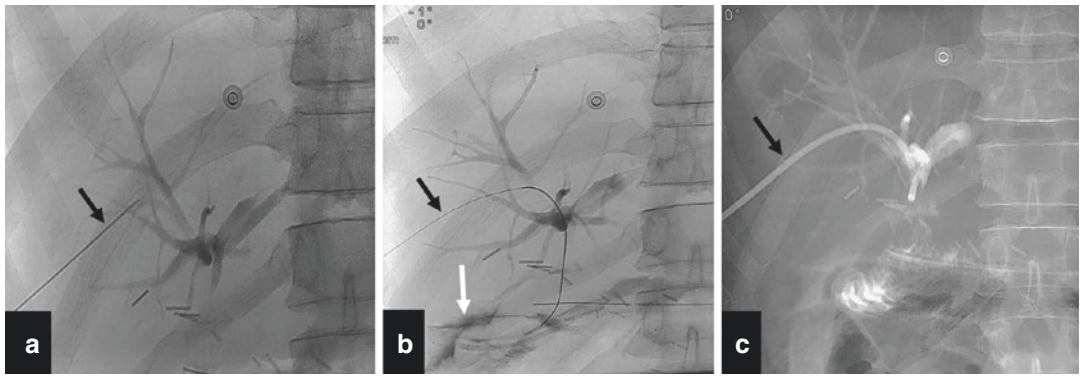

Fig. 2.29 PTBD for bile leak from bilio-enteric anastomosis. (**a**) Cholangiogram using 22G Chiba needle shows opacified bile ducts. (**b**) Guidewire (0.018 inch; black arrow) is passed into the duodenum through the anastomosis. Contrast leak (white arrow) is also seen. (**c**) Final placement of 8F pigtail catheter (arrow), proximal to the anastomotic site

2.8.2 Procedure

The patient should be prepared with broad-spectrum antibiotics, to reduce the risk of cholangitis and sepsis.

The most critical step of the procedure of PTBD done for bile leaks is the initial puncture of the ducts. Since there is bile leak, there is hardly any dilatation of the IHBD. In fact, the ducts are decompressed due to leak. Hence, USG guided puncture is mostly difficult. Fluoroscopy guidance along with USG is the preferred choice, usually from the right side.

The skin site chosen should be below the tenth intercostal space, in the mid axillary line, to avoid puncturing the pleura (Fig. 2.29) [47]. Further, central puncture of the ducts should be avoided. The puncture needle (22G, 15 cm) should be guided cranially by about 20^0 and anteriorly by about 20^0, and inserted for about

5–7 cm. The direction may be adjusted using USG as guidance to target the portal tract (bile ducts run parallel to the portal vein radicles). Then, contrast is injected slowly while withdrawing the needle. Once the biliary system is opacified, a wire (0.018 inch) is passed into the ducts (Fig. 2.29b). Subsequently, standard steps are followed. In most cases, an 8F pigtail catheter is placed for external drainage, with its tip proximal to the site of leak, so as to reduce the amount of bile reaching the site of leak (Fig. 2.29c). Internalization should be attempted in patients without signs of infection [48]. This gradually heals the surgical site, usually with the formation of fibrosis and often stricture. Similarly, the left duct may be punctured with a combination of USG and fluoroscopy, whenever the right duct puncture is difficult due to the small right lobe or large adjacent biloma (Fig. 2.30). Frequently, the drainage of biloma is also necessary.

The technical success of performing a PTBD for bile leak is in the range of 40–100% [49]. The complications are similar to that of PTBD done for malignant obstruction, but have a higher incidence due to non-dilated ducts [50].

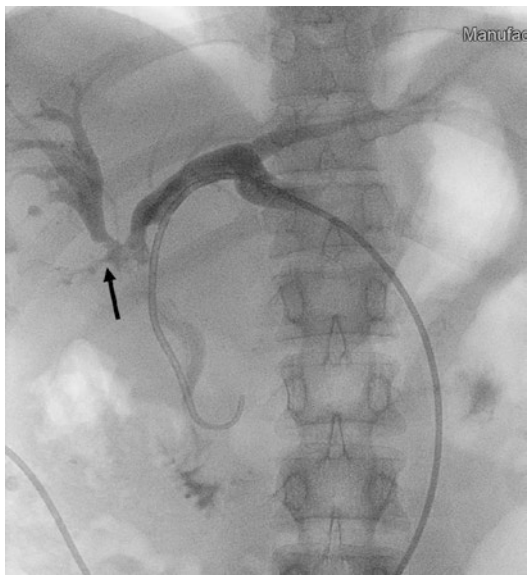

Fig. 2.30 PTBD for bile leak. Left PTBD with internal–external drainage catheter in a patient of post cholecystectomy bile leak from common hepatic duct (arrow)

2.9 Percutaneous Cholecystostomy

This is a technique where the gallbladder is drained percutaneously under USG guidance with the help of a catheter. This assists in decompressing an obstructed gallbladder or indirectly the biliary system.

2.9.1 Indications

The common indications include acute cholecystitis with impacted stone in the neck, empyema of the gallbladder, and bile duct obstruction (malignant or benign) with non-dilated IHBD, especially in patients who are poor candidates for surgery or EBD [51, 52]. It is also indicated in patients with malignant biliary obstruction when transhepatic biliary drainage is not possible due to multiple metastases or other diffuse liver diseases.

2.9.2 Procedure

The procedure is usually done under USG guidance or uncommonly under CT guidance, using the standard trocar or Seldinger technique performed for collection drainage [53]. The aim is to place a catheter into the distended gallbladder. It is performed usually under local anesthesia and mild sedation.

There are two approaches described in the literature. They are transhepatic route and transperitoneal route [54]. Both routes have their advantages and disadvantages. In transhepatic route, the needle path traverses some part of liver parenchyma before entering the gallbladder (Figs. 2.31 and 2.32). In transperitoneal route, the catheter enters the gallbladder directly from the abdominal wall, without liver intervening. The former approach is associated with reduced risk of bile leak, lesser chances of catheter dislodgement and earlier maturation of the tract, but higher risk of bleeding complications and fistula formation whereas the latter approach has higher incidence of biliary peritonitis [53, 55, 56]. However, a recent study

has shown that there is no significant difference between the two approaches in terms of complications [54]. The choice, thus, depends on the IR specialist and the patient factors like body habitus, intervening bowel loops, size of the gallbladder, and the thickness of the liver segment. It is important to note that there is a high chance of catheter dislodgement after cholecystostomy once the gallbladder decompresses after drainage. It is thus suggested that the puncture is made close to the region of the fundus of the gallbladder with sufficient length of the catheter pushed towards the neck region to reduce the chances of catheter displacement. Once cholecystostomy is done, the catheter should preferably be left in place for at least 2 weeks. This will lead to the formation of tract around the catheter and thus avoids any complications due to bile leak. After catheter removal, the tract will eventually close, provided the normal drainage path of the gallbladder is patent.

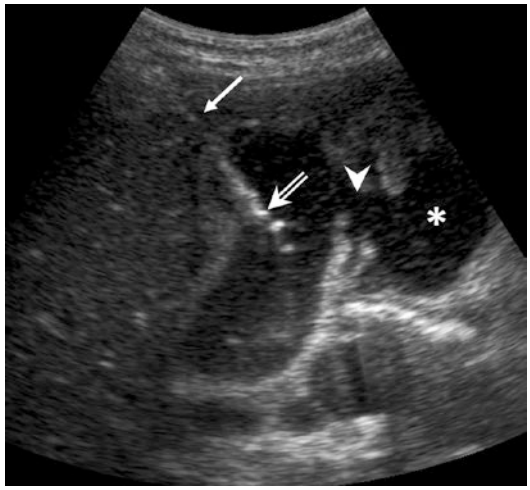

Fig. 2.31 Cholecystostomy. Ultrasonography guided percutaneous cholecystostomy (open arrow) through transhepatic route (arrow) in a case of complicated cholecystitis with perforation (arrow head) and pericholecystic collection (asterisk)

2.9.3 Complications [56]

Bile leak—it is one of the important complications of percutaneous cholecystostomy. It is more common when a transperitoneal approach is used. There may be bile leak around the catheter or through partial displaced catheter into the peritoneal cavity. This leads to biliary peritonitis and biloma formation. It is best to try and prevent such complications. The removal of catheter should be avoided before 2 weeks. Few studies suggest doing a cholecystogram before removal of the catheter to check for any leaks (Fig. 2.32c). Biloma, once formed, should be drained with a pigtail catheter.

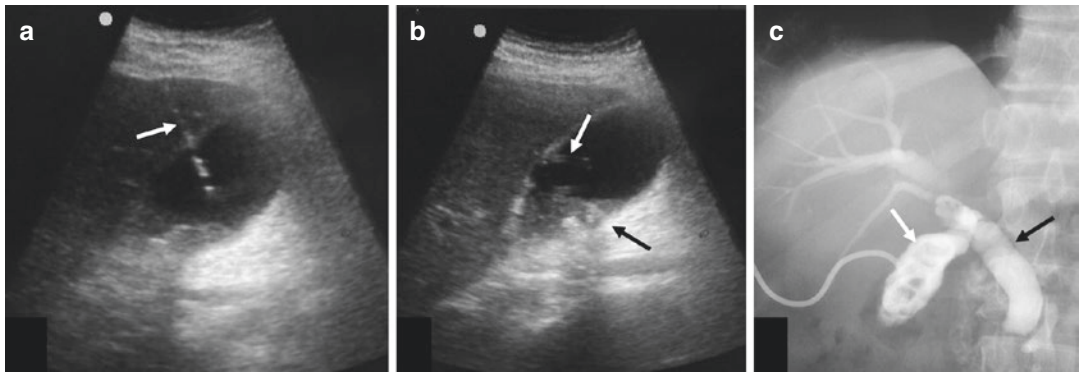

Fig. 2.32 Percutaneous cholecystostomy in a case of gallbladder empyema with gall stones. (**a**) USG guided transhepatic cholecystostomy (arrow). (**b**) USG image shows pigtail catheter in the lumen of gallbladder (white arrow) with calculi and sludge (black arrow). (**c**) Cholecystogram shows multiple calculi in the gallbladder (white arrow) as filling defects with dilated common bile duct (black arrow). This route can be used to perform biliary interventions

Hemorrhage—it is mostly self-limiting. In cases of persistent hemorrhagic fluid draining from the catheter, CT angiogram should be done to look for the cause of bleeding. If any arterial source is found, e.g., cystic artery or hepatic artery pseudoaneurysm, DSA and embolization should be done.

Catheter dislodgement—this is a common complication. Adequate care must be taken to ensure insertion of a good length of the catheter into the gallbladder lumen, optimal fixing the catheter and its maintenance. Locking pigtail catheter should be placed, if possible. If the catheter is partially displaced, it should be repositioned. If repositioning fails or if the catheter is completely dislodged, performing a repeat procedure may be difficult as the gallbladder will be completely collapsed. Depending on the need for a repeat cholecystostomy, the patient may be kept under observation until gallbladder distends sufficiently or the patient does not respond to treatment.

Pericatheter leak and *low or absent drain output* may suggest occlusion of the catheter with debris and sludge and need replacement of the catheter, with a larger size.

Other complications, like cholangitis, skin infection, and abscess, require treatment with antibiotics. Local pain is managed by analgesics.

2.9.4 Transcholecystic Interventions

Percutaneous cholecystostomy may be used as an access route for performing some biliary interventions [57, 58]. This is done in benign as well as malignant biliary obstructions. The procedures done include placement of internal drainage catheters, stent placement, and stone extraction. These are done under fluoroscopy guidance.

The procedures should be performed after maturation of the tract which takes 2–3 weeks. The drainage catheter is exchanged for a sheath (6–8F) over a wire. Then with the use of an angled catheter and hydrophilic guidewire, the cystic duct is crossed and the bile duct is entered. Then, the obstruction is crossed with the same wire and catheter to enter the duodenum. Subsequently, a stiff guidewire is placed to replace the hydrophilic soft wire. This can then be used to perform various interventions. A ring biliary catheter or SEMS may be placed as indicated, for internal drainage. Removal of bile duct stones may also be attempted with the help of a balloon catheter. The tract may be widened from 20F to 26F for removal of gall stones in patients who are not fit for surgery due to comorbid conditions. Tortuous cystic duct may pose a problem sometimes, especially if the obstruction is mild. Major complications like hemorrhage, bile leak, and pneumothorax are uncommon, seen in <5% patients [56].

2.10 Conclusion

Biliary interventions are important non-vascular interventional procedures which should be learned by every IR specialist. Being well versed with the basic steps of the commonly performed biliary interventions described here is critical for a successful procedure with minimal complications. Knowledge of the complications will help in their appropriate evaluation and treatment, when necessary. The protocol for managing benign biliary strictures percutaneously is evolving; long-term placement of larger catheters seems to be the feasible option. Further research in this aspect is ongoing and their results may help optimize the protocol.

References

1. Perez-Johnston R, Deipolyi AR, Covey AM. Percutaneous biliary interventions. Gastroenterol Clin N Am. 2018;47:621–41.
2. Madhusudhan KS, Gamanagatti S, Srivastava DN, Gupta AK. Radiological interventions in malignant biliary obstruction. World J Radiol. 2016;8(5):518–29.
3. Riaz A, Pinkard JP, Salem R, Lewandowski RJ. Percutaneous management of malignant biliary disease. J Surg Oncol. 2019;120:45–56.
4. Eklund JW, Trifilio S, Mulcahy MF. Chemotherapy dosing in the setting of liver dysfunction. Oncology (Williston Park). 2005;19(08):1057–63.
5. Ahmed O, Mathevosian S, Arslan B. Biliary interventions: tools and techniques of the trade, access, cholangiography, biopsy, cholangioscopy, cholangio-

plasty, stenting, stone extraction and brachytherapy. Semin Intervent Radiol. 2016;33:283–90.
6. Funaki B. Percutaneous biliary drainage. Semin Intervent Radiol. 2007;24(2):268–71.
7. Patel IJ, Davidson JC, Nikolic B, Salazar GM, Schwartzberg MS, Walker TG, et al. Consensus guidelines for periprocedural management of coagulation status and hemostasis risk in percutaneous image-guided interventions. J Vasc Interv Radiol. 2012;23:727–36.
8. Venkatesan AM, Kundu S, Sacks D, Wallace MJ, Wojak JC, Rose SC, et al. Practice guidelines for adult antibiotic prophylaxis during vascular and interventional radiology procedures. Written by the Standards of Practice Committee for the Society of Interventional Radiology and Endorsed by the Cardiovascular Interventional Radiological Society of Europe and Canadian Interventional Radiology Association. J Vasc Interv Radiol. 2010;21:1611–30.
9. Kumar Behera R, Narayan Srivastava D, Kumar P, et al. Right-sided versus left-sided percutaneous transhepatic biliary drainage in the management of malignant biliary obstruction: a randomized controlled study [published online ahead of print, 2020 Jul 22]. Abdom Radiol (NY). 2020. https://doi.org/10.1007/s00261-020-02651-y.
10. Weber A, Gaa J, Rosca B, Born P, Neu B, Schmid RM, et al. Complications of percutaneous transhepatic biliary drainage in patients with dilated and nondilated intrahepatic bile ducts. Eur J Radiol. 2009;72:412–7.
11. Aung TH, Too CW, Kumar N, Damodharan K, Urlings TA, Patel A, et al. Severe bleeding after percutaneous transhepatic drainage of the biliary system. Radiology. 2016;278:957–8.
12. Quencer KB, Tadros AS, Marashi KB, Cizman Z, Reiner E, O'Hara R, et al. Bleeding after percutaneous transhepatic biliary drainage: incidence, causes and treatments. J Clin Med. 2018;7:94.
13. Madhusudhan KS, Dash NR, Afsan A, Gamanagatti S, Srivastava DN, Gupta AK. Delayed severe Hemobilia due to Bilio-venous fistula after percutaneous transhepatic biliary drainage: treatment with covered stent placement. J Clin Exp Hepatol. 2016;6(3):241–3.
14. Inal M, Aksungur E, Akgul E, Oguz M, Seydaoglu G. Percutaneous placement of metallic stents in malignant biliary obstruction: one-stage or two-stage procedure? Pre-dilate or not? Cardiovasc Intervent Radiol. 2003;26:40–5.
15. Chatzis N, Pfiffner R, Glenck M, Stolzmann P, Pfammatter T, Sharma P. Comparing percutaneous primary and secondary biliary stenting for malignant biliary obstruction: a retrospective clinical analysis. Indian J Radiol Imaging. 2013;23:38–45.
16. Gwon DI, Ko GY, Kim JH, Yoon HK, Lee IS, Kim KA, et al. A comparative analysis of PTFE-covered and uncovered stents for palliative treatment of malignant extrahepatic biliary obstruction. AJR Am J Roentgenol. 2010;195(6):W463–9.
17. Hyun H, Choi SY, Kim KA, Ko SB. Safety and efficacy of percutaneous biliary covered stent placement in patients with malignant biliary hilar obstruction; correlation with liver function. Cardiovasc Intervent Radiol. 2016;39(09):1298–305.
18. Shim DJ, Gwon DI, Han K, Kim Y, Ko GY, Shin JH, et al. Percutaneous metallic stent placement for palliative management of malignant biliary Hilar obstruction. Korean J Radiol. 2018;19(4):597–605.
19. Lee DH, Yu JS, Hwang JC, Kim KH. Percutaneous placement of self-expandable metallic biliary stents in malignant extrahepatic strictures: indications of transpapillary and suprapapillary methods. Korean J Radiol. 2000;1:65–72.
20. Jo JH, Park BH. Suprapapillary versus transpapillary stent placement for malignant biliary obstruction: which is better? J Vasc Interv Radiol. 2015;26(04):573–82.
21. Fu YF, Zhou WJ, Shi YB, Cao W, Cao C. Percutaneous stenting for malignant hilar biliary obstruction: a randomized controlled trial of unilateral versus bilateral stenting. Abdom Radiol (NY). 2019;44(8):2900–8.
22. Karnabatidis D, Spiliopoulos S, Katsakiori P, Romanos O, Katsanos K, Siablis D. Percutaneous trans-hepatic bilateral biliary stenting in Bismuth IV malignant obstruction. World J Hepatol. 2013;5:114–9.
23. Xing GS, Geng JC, Han XW, Dai JH, Wu CY. Endobiliary brush cytology during percutaneous transhepatic cholangiodrainage in patients with obstructive jaundice. Hepatobiliary Pancreat Dis Int. 2005;4(1):98–103.
24. Boos J, Yoo RJ, Steinkeler J, Ayata G, Ahmed M, Sarwar A, et al. Fluoroscopic percutaneous brush cytology, forceps biopsy and both in tandem for diagnosis of malignant biliary obstruction. Eur Radiol. 2018;28(2):522–9.
25. Brugge WR, De Witt J, Klapman JB, Ashfaq R, Shidham V, Chhieng D, et al. Techniques for cytologic sampling of pancreatic and bile duct lesions: the Papanicolaou Society of Cytopathology Guidelines. Cytojournal. 2014;11(Suppl 1):2.
26. Mizandari M, Pai M, Xi F, Valek V, Tomas A, Quaretti P, et al. Percutaneous intraductal radiofrequency ablation is a safe treatment for malignant biliary obstruction: feasibility and early results. Cardiovasc Intervent Radiol. 2013;36(03):814–9.
27. Pai M, Valek V, Tomas A, Doros A, Quaretti P, Golfieri R, et al. Percutaneous intraductal radiofrequency ablation for clearance of occluded metal stent in malignant biliary obstruction: feasibility and early results. Cardiovasc Intervent Radiol. 2014;37(01):235–40.
28. Madhusudhan KS, Gamanagatti S, Gupta AK. Imaging and interventions in hilar cholangiocarcinoma: a review. World J Radiol. 2015;7(2):28–44.
29. Chen Y, Wang XL, Yan ZP, Cheng JM, Wang JH, Gong GQ, et al. HDR-192Ir intraluminal brachytherapy in treatment of malignant obstructive jaundice. World J Gastroenterol. 2004;10(23):3506–10.
30. Thompson CM, Saad NE, Quazi RR, Darcy MD, Picus DD, Menias CO. Management of iatrogenic

bile duct injuries: role of the interventional radiologist. Radiographics. 2013;33:117–34.
31. Zajko AB, Sheng R, Zetti GM, Madariaga JR, Bron KM. Transhepatic balloon dilation of biliary strictures in liver transplant patients: a 10-year experience. J Vasc Interv Radiol. 1995;6:79–83.
32. Janssen JJ, van Delden OM, van Lienden KP, Rauws EA, Busch OR, van Gulik TM, et al. Percutaneous balloon dilatation and long-term drainage as treatment of anastomotic and nonanastomotic benign biliary strictures. Cardiovasc Intervent Radiol. 2014;37:1559–67.
33. DePietro DM, Shlansky-Goldberg RD, Soulen MC, Stavropoulos SW, Mondschein JI, Dagli MS, et al. Long term outcomes of a benign biliary stricture protocol. J Vasc Interv Radiol. 2015;26:1032–9.
34. Cantwell CP, Pena CS, Gervais DA, Hahn PF, Dawson SL, Mueller PR. Thirty years' experience with balloon dilation of benign postoperative biliary strictures: long-term outcomes. Radiology. 2008;249:1050–7.
35. Bonnel DH, Fingerhut AL. Percutaneous transhepatic balloon dilatation of benign bilioenteric strictures: long term results in 110 patients. Am J Surg. 2012;203:375–83.
36. Saad WE, Davies MG, Saad NE, Waldman DL, Sahler LG, Lee DE, et al. Transhepatic dilation of anastomotic biliary strictures in liver transplant recipients with use of a combined cutting and conventional balloon protocol: technical safety and efficacy. J Vasc Interv Radiol. 2006;17:837–43.
37. Mukund A, Rajesh S, Agrawal N, Arora A, Arora A. Percutaneous management of resistant biliary-enteric anastomotic strictures with the use of a combined cutting and conventional balloon cholangioplasty protocol: a single-center experience. J Vasc Interv Radiol. 2015;26(4):560–5.
38. Bartel MJ, Higa JT, Tokar JL. The status of SEMS versus plastic stents for benign biliary strictures. Curr Gastroenterol Rep. 2019;21(7):29.
39. Yun G, Yoon CJ, Seong NJ. Percutaneous treatment of benign bilioenteric anastomotic strictures: temporary covered stent placement versus balloon dilatation. Eur Radiol. 2019;29(5):2690–7.
40. Mauri G, Michelozzi C, Melchiorre F, Poretti D, Pedicini V, Salvetti M, et al. Benign biliary strictures refractory to standard bilioplasty treated using polydoxanone biodegradable biliary stents: retrospective multicentric data analysis on 107 patients. Eur Radiol. 2016;26(11):4057–63.
41. Stokes KR, Clouse ME. Biliary duct stones: percutaneous transhepatic removal. Cardiovasc Intervent Radiol. 1990;13:240–4.
42. Ryu JK. Percutaneous approach for removal of difficult common bile duct stones. Clin Endosc. 2013;46(1):3–4.
43. Ozcan N, Kahriman G, Mavili E. Percutaneous transhepatic removal of bile duct stones: results of 261 patients. Cardiovasc Intervent Radiol. 2012;35:621–7.
44. Koch M, Garden OJ, Padbury R, Rahbari NN, Adam R, Capussotti L, et al. Bile leakage after hepatobiliary and pancreatic surgery: a definition and grading of severity by the International Study Group of Liver Surgery. Surgery. 2011;149:680–8.
45. Duconseil P, Turrini O, Ewald J, Berdah SV, Moutardier V, Delpero JR. Biliary complications after pancreaticoduodenectomy: skinny bile ducts are surgeons' enemies. World J Surg. 2014;38:2946–51.
46. Weber A, Feussner H, Winkelmann F, Siewert JR, Schmid RM, Prinz C. Long-term outcome of endoscopic therapy in patients with bile duct injury after cholecystectomy. J Gastroenterol Hepatol. 2009;24(5):762–9.
47. May K, Hunold P. Leakage of hepaticojejunal anastomosis: radiological interventional therapy. Visc Med. 2017;33:192–6.
48. Saad N, Darcy MD. Iatrogenic bile duct injury during laparoscopic cholecystectomy. Tech Vasc Interv Radiol. 2008;11(2):102–10.
49. Angileri SA, Gorga G, Tortora S, Avrilingi M, Petrillo M, Ierardi AM, et al. Biliary injuries after pancreatic surgery: interventional radiology management. Gland Surg. 2019;8:141–9.
50. Stampfl U, Hackert T, Radeleff B, Sommer CM, Stampfl S, Werner J, et al. Percutaneous management of postoperative Bile leaks after upper gastrointestinal surgery. Cardiovasc Intervent Radiol. 2011;34:808–15.
51. Akhan O, Akinci D, Ozmen MN. Percutaneous cholecystostomy. Eur Radiol. 2002;43:229–36.
52. Little MW, Briggs JH, Tapping CR, Bratby MJ, Anthony S, Phillips-Hughes J, et al. Percutaneous cholecystostomy: the radiologist's role in treating acute cholecystitis. Clin Radiol. 2013;68:654–60.
53. Venara A, Carretier V, Lebigot J, Lermite E. Technique and indications of percutaneous cholecystostomy in the management of cholecystitis in 2014. J Visc Surg. 2014;151:435–9.
54. Beland MD, Patel L, Ahn SH, Grand DJ. Image-guided cholecystostomy tube placement: short and long term outcomes of transhepatic versus transperitoneal placement. Am J Roentgenol. 2019;212:201–4.
55. Loberant N, Notes Y, Eitan A, Yakir O, Bickel A. Comparison of early outcome from transperitoneal versus transhepatic percutaneous cholecystostomy. Hepato-Gastroenterology. 2010;57:12–7.
56. VanSonnenberg E, D'Agostino HB, Goodacre BW, Sanchez RB, Casola G. Percutaneous gallbladder puncture and cholecystostomy: results, complications, and caveats for safety. Radiology. 1992;183:167–70.
57. Hatzidakis A, Venetucci P, Krokidis M, Iaccarino V. Percutaneous biliary interventions through the gallbladder and the cystic duct: what the radiologists need to know. Clin Radiol. 2014;69:1304–11.
58. Ginat D, Saad WE. Cholecystostomy and transcholecystic biliary access. Tech Vasc Interv Radiol. 2008;11:2–13.

3 Percutaneous Image Guided Management of the Cysts and Cyst-Like Lesions of Liver

Ashish Verma and Ishan Kumar

3.1 Historical Perspective

The term Interventional Radiology was coined by Margulis, describing the percutaneous removal of residual gall stones [1, 2]. Hacncke first describes tissue sampling under A-mode ultrasound guidance for pancreatic lesion biopsy [3]. Haaga and Alfridi first used CT scan guidance for pancreatic biopsy and liver abscess drainage [4]. Ultrasound guided interventional procedures began in the early 1970s with Holm et al. and Goldberg et al. who developed special transducers ("bioptic probes") with central holes in it for needle insertion [5, 6]. Real-time guidance by ultrasound began in the late 1970s and early 1980s, with several publications from Japanese investigators using real-time sonographic guidance for needle puncture [7]. Soon ultrasound guidance for abdominal fluid collections became increasingly popular and thereafter became part of routine management strategy [8].

3.2 Approach to Liver Cyst

Cystic lesions of liver (Fig. 3.1) consist of the near fluid attenuation lesions of various etiologies. They can be broadly categorized into developmental, neoplastic, infective, and miscellaneous group [9]. Over the last two decades, the advent of high-resolution USG, CT scan, and MRI combined with diligently obtained clinical history has enhanced our ability to differentiate between these lesions, which has significantly improved the management course [10, 11]

USG is the most accurate and effective modality in diagnosing and characterizing cystic lesion of the liver is often the first modality to identify the presence of these lesions. In most of cases diagnosis of cystic lesion of the liver is straightforward on sonography, however, sometimes imaging features of etiological diagnosis of cyst overlap and can be confusing. Evaluation of these cysts on Imaging (USG, CT, or MRI) should include a step by step characterization of the cyst contents, shape, wall, border, septations, solid nodule, calcification, and adjacent hepatic tissue. Strong posterior wall echoes suggest well-defined fluid tissue interface [10–12]. In addition, color Doppler evaluation of the lesions should complement USG evaluation to distinguish between cystic lesion and hypoechoic cyst-like mass. Assessment of contrast uptake on CT and MRI can provide supportive evidence to characterize the lesion.

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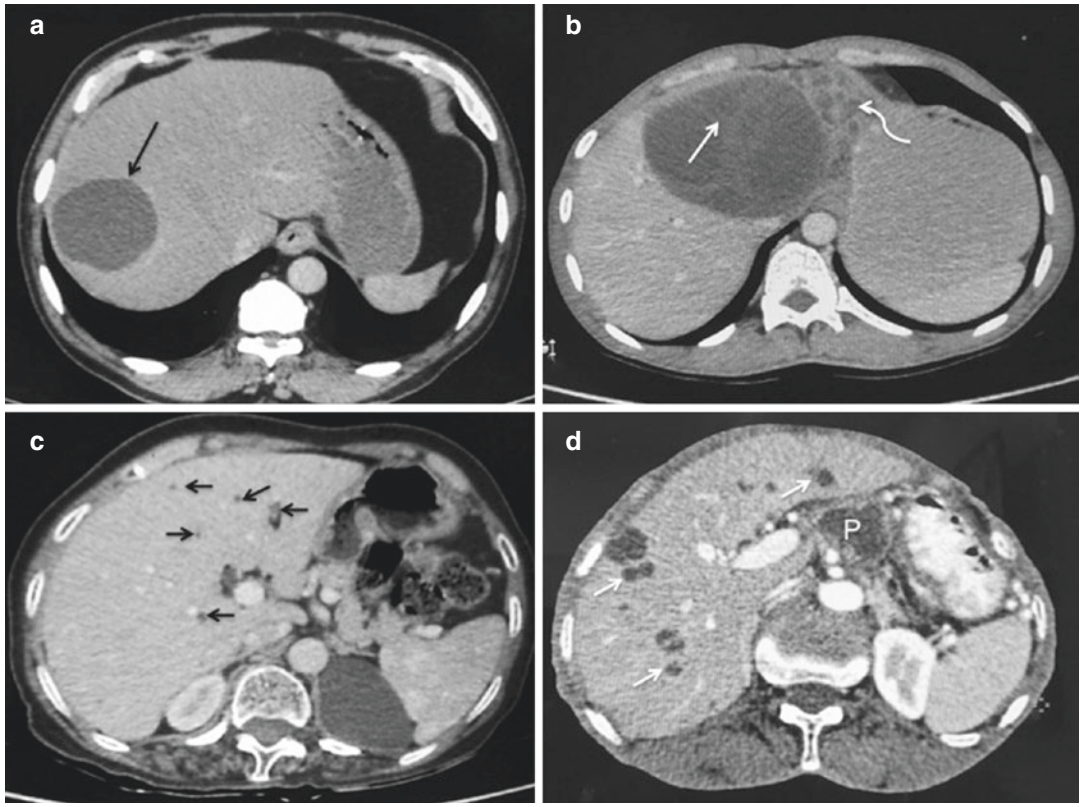

Fig. 3.1 Cystic lesions of liver. (**a**) Simple hepatic cyst in right lobe of liver. Note thin but minimally enhancing wall (long black arrow) which is likely due to secondary infection. (**b**) Hydatid cyst in segment IV of liver showing multiple intralesional septations (long white arrow). The lesion shows frank biliary communication with intrahepatic biliary dilatation (curved white arrow) and atrophy of left lobe of liver. (**c**) Von Meyenberg complex. Multiple tiny (few mm) cysts (short black arrows) scattered in both lobes of liver without any communication with biliary channels suggestive of biliary Hamartoma. (**d**) Cystic metastasis. Multiple variable sized cystic lesions in both lobes of liver with enhancing walls (short white arrows). Note is made of a cystic tumor of pancreatic body (P)

3.3 Infective Lesions

3.3.1 Liver Abscess

Percutaneous drainage is the first-line treatment of pyogenic, amoebic, or fungal abscess. Percutaneous needle aspiration and percutaneous catheter drainage both are equally effective for smaller abscesses, however, percutaneous catheter drainage is more effective in lesions >5 cm [13]. For multiple abscesses, multiple catheters are well tolerated and should be performed [14, 15]. Catheter drainage is most commonly performed using Seldinger's technique [16]. The exact drainage procedure has been described in detail in the first chapter of this book.

3.3.2 Hydatid Cyst

Various treatment options are available for hydatid cysts ranging from pharmacotherapy to percutaneous treatment and surgical procedures, and the best option is still debated. Medical treatment alone is associated with high relapse rate (up to 30%) and low success rate (20–50%) [17]. Surgical resection has been considered gold standard for the treatment of hepatic Hydatid cysts. Percutaneous aspiration, injection (of scolicidal agents) and re-aspiration (PAIR) is a reliable and efficient therapeutic option, which has become increasingly as an alternative to surgery. Treatment of these lesions requires individualized approach based on cyst morphology

(Fig. 3.2), location, and clinical status of the patient. An ultrasound-based classification system devised by the WHO for hydatid cysts is given in Table 3.1.

Size of all these lesions is added to the classification as s (<5 cm), m (5–10 cm) and l (>10 cm).

Indications and contraindications of PAIR technique have been summarized in Table 3.2. [19]

Pre-procedure: informed consent should be obtained with detailed counseling of the patient regarding the risk of anaphylaxis. If the patient is on beta-blocker, it should be replaced by any other suitable drug for 1 week before the procedure. Epinephrine, hydrocortisone, antihistaminic agents, basic resuscitation equipment, blood pressure monitoring should be available before the procedure and IV cannula should be inserted for emergency drug administration. In case of anaphylaxis mild skin reaction can be managed with injection hydrocortisone and antihistaminic agents. For moderate hypotension, procedure should be temporarily stopped and BP should be monitored. For marked hypotension (<95/50 mm Hg), 1/3 mL of epinephrine (1 mg/mL) IM or (3 mL of a saline solution of epinephrine-1 mL/10 mL-through should be injected through the IV catheter and emergency team should be informed [19–22].

Procedure: The procedure should be done under albendazole prophylaxis at least 4 h before the procedure. Puncture of the cyst should be done

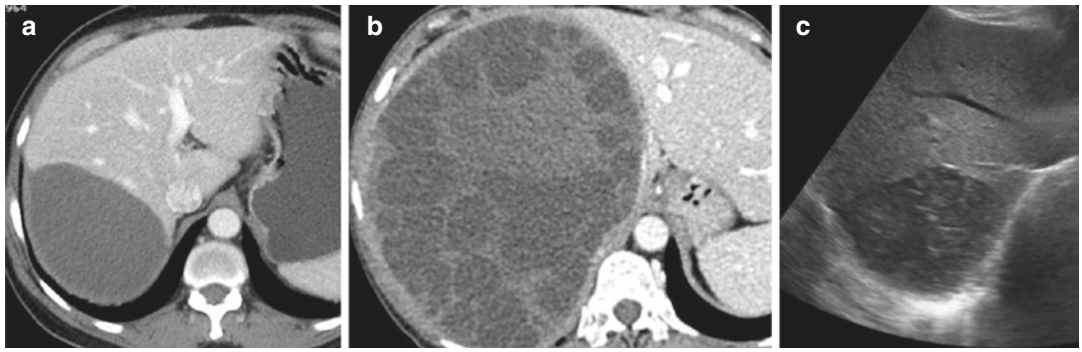

Fig. 3.2 Hydatid cysts. (**a**) Unilocular, thick walled cyst in right lobe of liver (CE1 cyst). (**b**) Unilocular, multiseptated, multivesicular cysts with multiple daughter cyst demonstrating honeycomb pattern (CE2 cyst). (**c**) Solid appearing heterogenous hyperechoic unilocular cyst (CE4 cyst)

Table 3.1 WHO-IWGE classification of ultrasound images of cystic echinococcosis cysts [18]

Classification	Loculation	Content	Additional feature	Wall
CL	Unilocular	Anechoic	None	Hyperechoic rim or thin imperceptible wall
CE1	Unilocular	Anechoic	Fine echoes Hydatid sand Snowflake sign	Thick wall
CE2	Unilocular mother cyst	Multiseptated Multivesicular Daughter cysts	Spoke wheel appearance Rosette/Honeycomb appearance	Thick wall
CE3	Unilocular mother cyst	Anechoic content	Laminated detached membrane (water lily sign)	Thick wall
CE4	Unilocular	Heterogenous (Hypo to hyperechoic) No daughter cyst	Degenerating membranes (ball of wool sign)	Thick wall
CE5	Variable	Variable	Variable	Thick calcified wall (partial/complete)

Table 3.2 Indications and contraindications of PAIR technique

Indications	Contraindications
• Solitary CE1m, CE1, CE2, CE3 lesions • Multiple lesions if safe percutaneous approach available • Infected Hydatid cyst • Patients who do not respond to medications, having contraindication to surgery.	• CE4, CE5 (inactive) lesions • Cyst with biliary communication • Presence of fat density contents within the lesion on CT scan • Cyst with rupture into peritoneum, lungs, or urinary tract • Risky percutaneous approach

under ultrasound guidance and puncture should be done via normal hepatic parenchyma. A drainage catheter can be used if the cyst is large. After the puncture of cyst, 10–15 ml fluid is aspirated and evaluated for biliary content (if fast dipstick test for bilirubin is available). Otherwise, iodinated contrast is injected into the lesion and biliary communication should be ruled out under fluoroscopy. In the presence of bilirubin content or biliary communication, the procedure should be stopped. Otherwise, the contents of the cyst should be completely aspirated. After complete aspiration, injection of 95% ethanol or 20% hypertonic saline should be injected (1/3rd of the original cyst volume). After 5 min (20 min for hypertonic saline), the contents should be re-aspirated. [19–22]

Various modification of this PAIR technique has been attempted with variable results.

- The cysts with solid component, multivesiculated, and daughter cysts (type CE3B) tend to relapse after PAIR. Those cysts have been treated by percutaneous evacuation or modified catheterization technique (MoCaT) using a 14/16F drainage catheter inserted into the cyst and complete aspiration of cyst contents including membranes, solid components, daughter cysts, and/or infected material by irrigation with hypertonic saline. After the complete evacuation, a smaller catheter (8/10 F) is placed into the cyst until fluid drainage is <10 mL/day [23]. (Fig. 3.3)
- Another technique is percutaneous aspiration and injection (PAI) of albendazole into the cyst cavity and no subsequent re-aspiration, which has been found to be equally effective to PAIR technique [24].
- Nayman et al. have performed the PAIR by direct catheterization of the cyst using trocar catheter and have advocated its use over puncture needle or catheterization by Seldinger's technique [25].
- A modification of PAIR used an especially designed coaxial catheter system to achieve concomitant evacuation of cyst contents while infusing hypertonic saline followed by injection of 95% ethyl alcohol into the residual cyst cavity. [26]
- A technique by Örmeci et al. [27] uses 22-gage Chiba needle for puncture and aspiration of 12–40 ml of content with subsequent injection equal amount of 2/3 volume of pure alcohol (95%) and 1/3 volume ethoxysclerol (1% polidocanol) into the cyst and no subsequent re-aspiration. The study justifies small amount of content aspiration to prevent negative pressure in the cyst and thus preventing filling-in of bile into cyst in cases of unrecognized biliary fistula (Fig. 3.4). Thin puncture needle has been advocated to prevent content leakage into the peritoneum.
- PEVAC (percutaneous evacuation of cyst content) is another modification of PAIR which consists of (1) puncture and aspiration of cyst fluid, (2) insertion of a large-bore catheter, aspiration and evacuation of daughter cysts and endocyst by repetitive injection and re-aspiration of isotonic saline (3) cystography to rule out biliary fistula (4) injection of hypertonic saline in absence of fistula. A second session is also performed with replacing the catheter with a 14–18 F stiff sheath and evacuation of residual cyst content by a suction catheter. [28]
- Saremi et al. have used a special cutting instrument to fragment and evacuate daughter cysts and laminated membrane while the cavity is continuously irrigated with scolicidal [29].
- Percutaneous aspiration, injection with catheter drainage, and injection of sclerosing agents (PAIDS) procedure has been described for cysts larger than 6 cm, in which, punc-

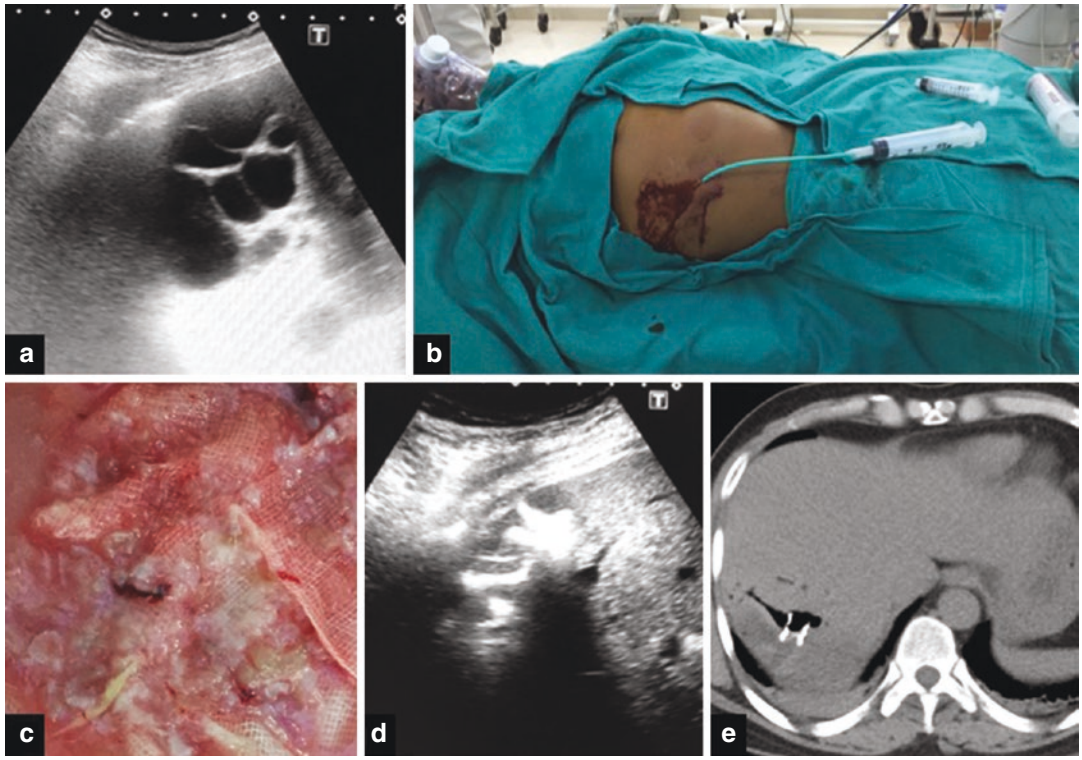

Fig. 3.3 Modified catheterization technique (MoCaT) for cysts with solid component, multi-vesiculated and daughter cysts. Ultrasound image (**a**) shows thick walled multi-vesiculated cyst (**b**) shows drainage being performed with wide bore catheter (14/16F) inserted into the cyst and complete aspiration of cyst with image (**c**) showing cyst contents comprising of membranes, solid components, daughter cysts. Ultrasound image (**d**) shows change in internal echogenicity post alcohol injection (after content aspiration) and CT image (**e**) shows complete evacuation of cyst with contents

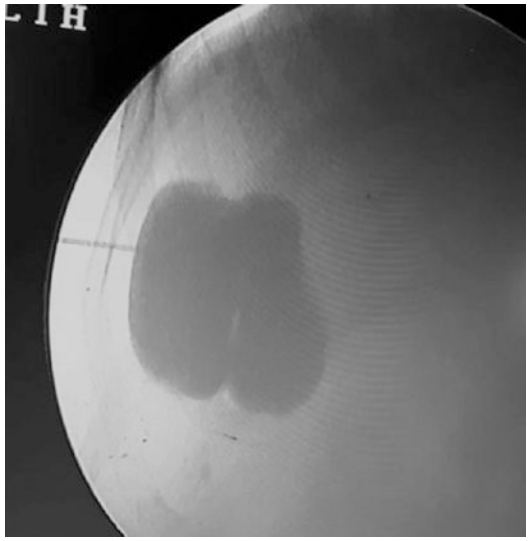

Fig. 3.4 Contrast injection into liver cyst under fluoroscopic guidance to rule out biliary fistula before sclerotherapy

ture, aspiration, and injection of the scolicidal agent is done and 8 F drainage catheter is inserted into the cavity contents are re-aspirated through. The catheter is kept until fluid drainage becomes <10 mL/day. Then, a cystogram is done to rule out biliary fistula following which, 95% absolute alcohol (25–35% of the estimated cyst volume) is injected for 15 min. Complete re-aspiration is subsequently done and the catheter is removed [23].

- Vuitton et al. have used a device named dilatable-multifunction trocar (DMFT) for multi-vesiculated abdominal cysts, which was linked to an aspiration apparatus to extract the endocyst, daughter cysts, and other cystic contents. Thereafter, the cavity was irrigated with 10–20% saline and if necessary curettage was performed [30].

3.4 Simple Cyst

Simple cysts are identified as anechoic thin, imperceptible walled, rounded, or ovoid lesion with a smooth border on sonography [31, 32]. They can be present in up to 3% of the normal population [33]. They are usually <5 cm, however, they can be of large size. These lesions are often multiple and show variable sizes. Rarely septation or calcification can be seen in these lesions. Echogenic contents on USG or higher attenuation value on CT can be present if there is intralesional hemorrhage or infection. On Imaging, note should be made if the lesions cause mass effect over the intrahepatic vessels, biliary channels, leading to segmental biliary dilations or deforming the liver capsule (Fig. 3.5) [10]

Majority (90%) of the simple hepatic cysts are asymptomatic and do not require treatment [34–36]. Uncommonly these lesions can lead to abdominal pain, epigastric fullness, flatulence, nausea, vomiting, early satiety, dyspnea, irregularities in liver function tests, and jaundice [37]. Pain can be caused due to its rapid enlargement or bleeding into cyst walls (Fig. 3.5). Other causes of the associated symptoms such as cholelithiasis, gastritis, reflux esophagitis, renal colic should be ruled out before commencement of treatment [34, 38]. Traditionally liver cyst is treated with surgical excision, cyst marsupialization, laparoscopic fenestration, or laparoscopic partial excision [39, 40]. Percutaneous drainage of the simple hepatic cysts is associated with high relapse rate (70–100%) [34, 41] Percutaneous drainage along with chemical obliteration of the cyst wall is associated with the better outcome both in terms of symptomatic relief as well as radiological resolution. [34] Indications and contraindications of percutaneous sclerotherapy have been summarized in Table 3.3.

Aspiration of simple hepatic cysts should be done using a 7–9 F drainage catheter (Malecot/pigtail drainage catheter) insertion using Seldinger's technique. The fluid aspirated from the cyst should be sent for bacteriological evaluation, detection of biliary content, as well as cytological evaluation for neoplastic cells. Before the injection of sclerosant, contrast should be injected into the cyst under fluoroscopic guidance to rule out biliary communication or peritoneal rupture. After complete aspiration of the cyst content, 94% ethyl alcohol is injected into the

Table 3.3 Indications and contraindications of percutaneous sclerotherapy in Simple Hepatic cysts

Indications	Contraindications
A large cyst or significant symptoms Mass effect over biliary channels/IHBRD Infected cyst Diagnostic uncertainty	Asymptomatic or incidentally detected cysts Communication with biliary channels

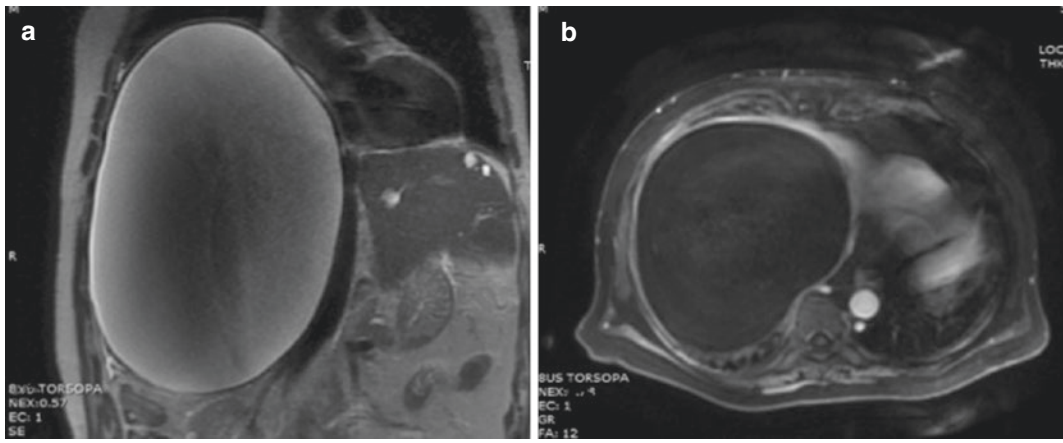

Fig. 3.5 Simple hepatic cyst: Coronal T2 weighted (**a**) and axial post contrast (**b**) image showing large simple hepatic cyst near completely occupying right lobe of liver causing upward displacement of right hemidiaphragm

cyst cavity for causing dehydration and subsequent fibrosis of the cyst wall ependyma. Amount of alcohol injected should be roughly equal to roughly 20–25% of the original cyst volume, not exceeding 100–120 ml. The drainage catheter should be subsequently clamped and injected content should be left in the cavity for 20–30 min. The patient should be made to change the position from supine to right and left decubitus every 8–10 min. The content should be completely re-aspirated. Injection of alcohol may sometimes lead to pain, vomiting, pyrexia, alcohol intoxication, or hemorrhage in the cyst cavity [34, 42]. In cases of severe pain, the procedure should be stopped, and alcohol should be completely aspirated, followed by injection of lidocaine via the catheter. Owing to the side effects of the alcohol injection various agents have been tried for cyst obliteration such as tetracycline, doxycycline, povidone-iodine, cyanoacrylate, ethanolamine oleate, minocycline hydrochloride, polidocanol, and concentrated hypertonic 10% sodium chloride solution [34]. The follow-up of the patients should be done with clinical and radiological parameters. On sonography recrudescence of the lesion has been considered if the cyst diameter becomes more than 75% of the pretreatment diameter [41].

3.5 Polycystic Liver Disease

Polycystic liver disease is associated with autosomal dominant polycystic kidney disease and is characterized by multiple (often innumerable) liver cysts with variable sizes [10, 43]. Secondary complications such as hemorrhage and infection, and calcification (due to old hemorrhage) is more common than simple hepatic cyst. [10]

Treatment of polycystic liver disease is controversial and challenging. Since polycystic liver disease is associated with polycystic kidney disease, it is difficult to ascertain whether the symptom of patient is due to renal complications, or liver disease. The presence of liver nodules or frank hepatic malignancies should be excluded on imaging. Management strategies for polycystic liver disease include percutaneous aspiration with sclerotherapy, surgical drainage with cystojejunostomy, surgical deroofing, segmental hepatectomy, liver transplant, or hepatic artery embolization. [44–46]. Percutaneous drainage combined with sclerotherapy is considered as an appropriate first-line therapy [38]

For percutaneous treatment of PCLD, a 7–9 mm drainage catheter (Pigtail/Malecot) should be first inserted within the cyst cavity using Seldinger's technique. Cyst contents should be entirely aspirated and should be sent for evaluation for bacteriological and neoplastic cell evaluation. Before the injection of sclerosant, contrast should be injected into the cyst under fluoroscopic guidance to rule out biliary communication or peritoneal rupture [44]. For occlusion of the cyst wall, studies have shown that injection of ethanol is associated with high degree of relapse [38, 47] and injection of ethanolamine oleate has been shown to have better outcome [44]. A volume approximately 10% of the initial cyst volume of ethanolamine oleate is injected into the cyst and the catheter is clamped for 30 min. Patient is made to change position every 8–10 min to ensure adequate contact between cyst wall and the sclerosing agent. Subsequently, the content of the cyst is completely aspirated. Nakaoka et al. have advocated retaining the catheter for 24 h of open drainage and subsequent removal to facilitate sustained sclerosis of the cyst wall [44]. In cases of recurrence, the procedure can be repeated after 6 months.

3.6 Caroli's Disease

Caroli's disease (Fig. 3.6) is characterized by segmental or diffuse saccular or fusiform dilatation of intrahepatic biliary channels, intraluminal bulbar protrusion, portal radicles surrounded by dilated biliary channels, or intrahepatic cysts communicating with biliary channels [48]. Stones, sludge, infective debris, and rarely cholangiocarcinoma are reported complications [49]. Treatment of Caroli's disease is partial hepatectomy in partial involvement and in cases of bilobar involvement cholecystectomy, hepaticojejunostomy in both lobes is performed [50].

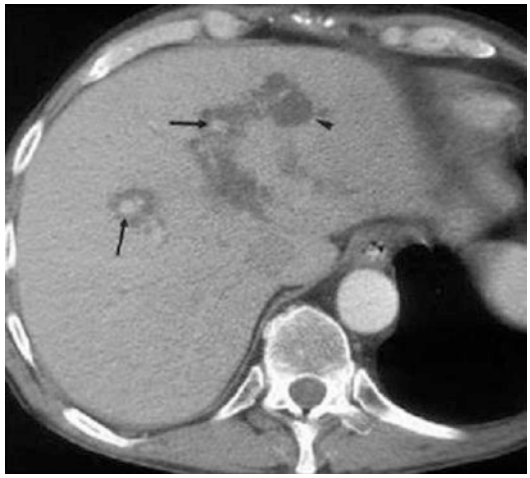

Fig. 3.6 Caroli's disease. Bilobar cystic dilatation of biliary channels (arrowhead) with central portal venous branch (arrow)

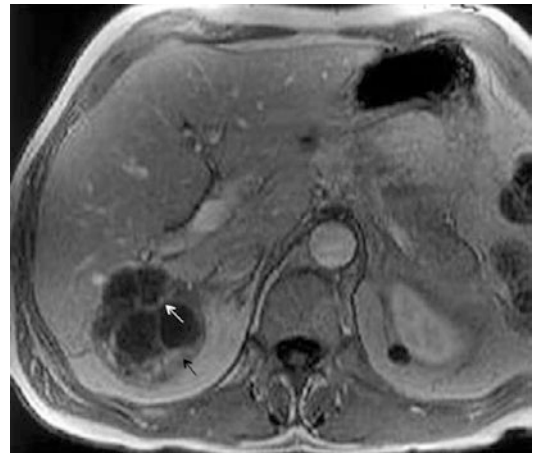

Fig. 3.7 Biliary cystadenoma: Thick walled multiseptated cyst with enhancing thick septations (white arrow) and papillary infolding from the wall (black arrow). Note that Hydatid cyst is an imaging differential consideration

Recurrent suppurative cholangitis, cholangitic abscess, intrahepatic calculi are the main complication of Caroli's disease which may mandate a long-term or emergency percutaneous transhepatic biliary drainage before definitive surgical treatment. [51, 52]. Percutaneous drainage should be done using a long-term ring biliary catheter with its tip placed in the duodenum.

Intermittent external drainage should be done to decompress the biliary system and prevent bacterial overgrowth. The biliary access via the ring biliary catheter can be used for tube exchange, stone extraction, or infusion of antibiotics when necessary [52].

3.7 Neoplasm

Biliary cystadenoma and cystadenocarcinoma are slow-growing, multilocular cystic tumors arising from biliary channels (Fig. 3.7). On sonography, these are identified as multilocular cystic lesion with multiple septations, thick wall, mural nodules, papillary infolding, and wall calcification [53]. Hydatid cyst should always be considered as a differential diagnosis. Upstream bile duct dilatations, adjacent transient hepatic attenuation differences, left lobe location have been found to be suggestive CT findings present in the biliary cystic neoplasms [54]. Image guided aspiration is sometimes obtained which yields bile tinged fluid, unlike hydatid or other cysts [55]. Role of cyst fluid CA 19-9, carcinoembryonic antigen (CEA) analysis has been reported in diagnosis of biliary cystic neoplasms, however, not uniformly replicable in other studies [56–58]. Moreover, fine needle aspiration or biopsy has been associated with pleural and peritoneal dissemination and should be routinely avoided unless there is considerable diagnostic dilemma. Management is complete surgical resection and considering the high malignant potential, attempts at percutaneous aspiration, ethanol injection sclerotherapy should not be performed [56]. Hepatocellular carcinoma, intrahepatic papillary mucinous neoplasms, and hemangioma can sometimes present as cyst-like lesions. The cystic appearance of HCC is usually due to internal necrosis of large and rapidly growing tumors. Cystic degeneration in HCC may be a result of chemoembolization. [59]. A rare truly cystic variant of HCC has been reported in the literature with only few case reports. [60, 61]

Various metastatic lesions from hypervascular tumors (neuroendocrine, breast, lung carcinoma, melanoma) or mucinous adenocarcinoma (colon, ovarian carcinoma) have been reported to have cystic appearance [62, 63]. Mural nodule, irregular border, peripheral halo on USG, peripheral enhancement on CT/MRI point towards metastatic lesions [62]. Many of these lesions mimic liver abscesses, and biopsy is highly recommended before precautious catheter placement in case of atypical looking abscess, especially if multiple lesions are present. Placing a percutaneous catheter in cystic metastasis can lead to track seeding of the tumor and is contraindicated [64].

3.8 Miscellaneous

3.8.1 Biloma

Extravasation of bile into liver parenchyma or subcapsular space can lead to intrahepatic biliary collection (biloma) (Fig. 3.8). These may be due to a traumatic or iatrogenic surgical or ERCP procedures injury to intrahepatic bile duct branches. ERCP, laparoscopic cholecystectomy, percutaneous microwave/radiofrequency ablation, percutaneous ethyl alcohol injection, PTBD have been associated with intrahepatic biloma [65, 66]. Large or symptomatic biloma requires percutaneous drainage.

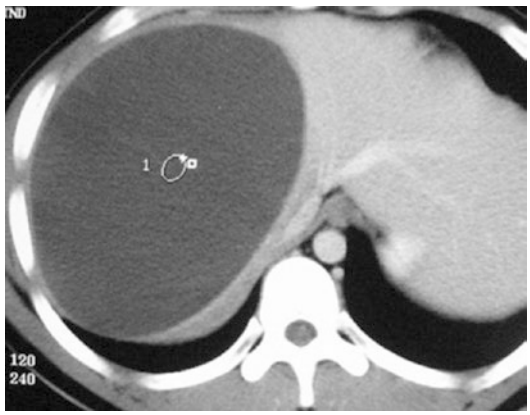

Fig. 3.8 Biloma: Large thick walled collection in liver parenchyma after cholecystectomy

Procedure: A drainage catheter (pigtail/Malecot) should be inserted using Seldinger's technique. Contrast should be injected by the catheter to identify the site of biliary injury. Catheter drainage should be continued until the bile output stops. Sometimes the drainage might be required to be converted to percutaneous transhepatic biliary drainage to divert bile for definitive treatment [65].

3.8.2 Intrahepatic Pseudocyst

The liver is a rare location for pancreatic pseudocyst and hence intrahepatic pseudocyst is not often included in the differential diagnosis of hepatic cysts. Furthermore, pancreatic and peripancreatic changes may be absent at the time of imaging in cases of delayed presentation. Percutaneous aspiration and demonstration of high amylase contents provide definitive diagnosis. Although there is no unequivocally optimal therapeutic option, Percutaneous aspiration or catheter drainage is the most common method with minimal complication. Upto 38% patients, however, require additional surgical or endoscopic intervention such as pancreatic duct balloon dilatation and stenting, transpapillary nasopancreatic drainage, or ERCP guided aspiration [67–69].

3.9 Summary

The most logical management of cystic lesions would depend upon the imaging morphology of the lesion (Fig. 3.9), this gives an added advantage as diagnostic impression can be made simultaneous to management and then tailored accordingly if additional information mandates so as in the case of biliary communication.

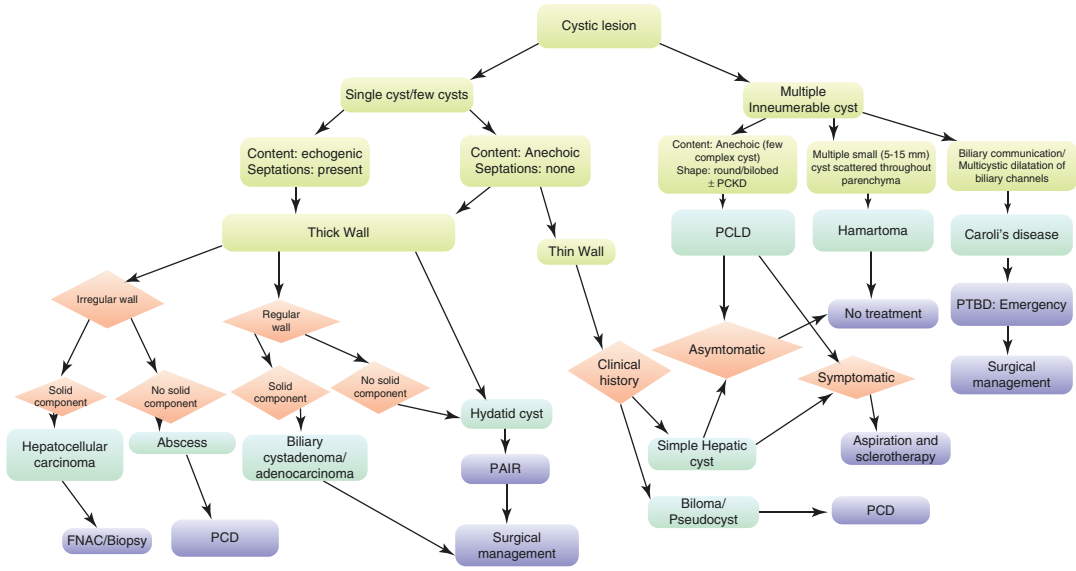

Fig. 3.9 Flowchart summarizing the algorithm for diagnosis and management of cystic lesions of liver

References

1. Dondelinger RF. A short history of non-vascular interventional radiology. J Belg Radiol. 1995;78(6):363–70.
2. Margulis AR. Interventional diagnostic radiology—a new subspecialty (Editorial). AJR Am J Roentgenol. 1967;99:761–2.
3. Hancke S, Holm HH, Koch F. Ultrasonically guided percutaneous fine needle biopsy of the pancreas. Surg Gynecol Obstet. 1975;140:361–4.
4. Haaga JR, Alfridi RJ. Precise biopsy localization by computed tomography. Radiology. 1976;118:603–7.
5. Goldberg BB, Pollack HM. Ultrasonic aspiration transducer. Radiology. 1972;102:187–9.
6. Holm HH, Rasmussen SN, Kristensen JK. Ultrasonically guided percutaneous puncture technique. J Clin Ultrasound. 1973;1:27–31.
7. Saitoh M, Watanabe H, Ohe H, Tanaka S, Itakura Y, Date S. Ultrasonic real-time guidance for percutaneous puncture. J Clin Ultrasound. 1979;7:269–72.
8. McGahan JP. The history of interventional ultrasound. J Ultrasound Med. 2004;23(6):727–41.
9. Vachha B, Sun MR, Siewert B, Eisenberg RL. Cystic lesions of the liver. AJR Am J Roentgenol. 2011 Apr;196(4):W355–66.
10. Del Frate C, Zuiani C, Bazzocchi M, Pozzi-Mucelli R, Brancatelli G, Mortelè K. Cysts and cystic-like lesions. In: Lencioni R, Cioni D, Bartolozzi C, editors. Focal liver lesions: medical radiology (Diagnostic imaging). Heidelberg: Springer; 2005.
11. Mortele K, Ros PR. Cystic focal liver lesions in the adult differential CT and MR imaging features. Radiographics. 2001;21:895–910.
12. Borhani AA, Wiant A, Heller MT. Cystic hepatic lesions: a review and an algorithmic approach. Am J Roentgenol. 2014;203:1192–204.
13. Dulku G, Mohan G, Samuelson S, Ferguson J, Tibballs J. Percutaneous aspiration versus catheter drainage of liver abscess: a retrospective review. Australas Med J. 2015;8(1):7–18.
14. Baijal SS, Agarwal DK, Roy S, Choudhuri G. Complex ruptured amebic liver abscesses: the role of percutaneous catheter drainage. Eur J Radiol. 1995 May;20(1):65–7.
15. Greenwood LH, Collins T, Yrizarry JM. Percutaneous management of multiple liver abscesses. Am J Roentgenol. 1982;139:390–2.
16. Nair AV, D'Agostino HR. Transcatheter fluid drainage. In: Valji K, editor. The practice of interventional radiology. Philadelphia: Saunders Elsevier; 2010. p. 106–25.
17. Gupta N, Javed A, Puri S, Jain S, Singh S, Agarwal AK. Hepatic hydatid: PAIR, drain or resect? J Gastrointest Surg. 2011 Oct;15(10):1829–36.
18. Group WHOIW. International classification of ultrasound images in cystic echinococcosis for application in clinical and field epidemiological settings. Acta Trop. 2003;85:253–61.
19. World Health Organization. PAIR: puncture, aspiration, injection, re-aspiration: an option for the treatment of cystic echinoccosis. Geneva: WHO; 2001.
20. Filice C, Pirola F, Brunetti E, Dughetti S, Strosselli M, Foglieni CS. A new therapeutic approach for hydatid liver cysts: aspiration and alcohol injection under sonographic guidance. Gastroenterology. 1990;98:1366–8.

21. Filice C, Strosselli M, Brunetti E, Colombo P, D'Andrea F. Percutaneous drainage of hydatid liver cysts. Radiology. 1992;184:617–20.
22. WHO Informal Working Group on Echinococcosis. Guidelines for treatment of cystic and alveolar echinococcosis in humans. Bull World Health Organ. 1996;25:655–89.
23. Kahriman G, Ozcan N, Dogan S, Karaborklu O. Percutaneous treatment of liver hydatid cysts in 190 patients: a retrospective study. Acta Radiol. 2017;58(6):676–84.
24. Paksoy Y, Ödev K, Şahin M, et al. Percutaneous treatment of liver hydatid cysts: comparison of direct injection of albendazole and hypertonic saline solution. AJR. 2005;185:727–34.
25. Nayman A, Guler I, Keskin S, et al. A novel modified PAIR technique using a trocar catheter for percutaneous treatment of liver hydatid cysts: a six-year experience. Diagn Interv Radiol. 2016;22(1):47–51.
26. Gabal AM, Khawaja FI, Mohammad GA. Modified PAIR technique for percutaneous treatment of high-risk hydatid cysts. Cardiovasc Intervent Radiol. 2005 Mar-Apr;28(2):200–8.
27. Örmeci N, Kalkan Ç, Karakaya F, et al. Percutaneous treatment with the Örmeci technique for hydatid disease located in the spleen: single center experience for twenty six years. Turk J Gastroenterol. 2018;29(5):566–73.
28. Schipper HG, Laméris JS, van Delden OM, et al. Percutaneous evacuation (PEVAC) of multivesicular echinococcal cysts with or without cystobiliary fistulas which contain non-drainable material: first results of a modified PAIR method. Gut. 2002;50: 718–23.
29. Saremi F, McNamara TO. Hydatid cysts of the liver: long-term results of percutaneous treatment using a cutting instrument. AJR Am J Roentgenol. 1995 Nov;165(5):1163–7.
30. Vuitton DA, Zhi Wang X, Li Feng S, Sheng Chen J, Shou Li Y, Li SF, et al. PAIR-derived US-guided techniques for the treatment of cystic echinococcosis: a Chinese experience (e-letter). Gut. 2002;
31. Lantinga MA, Gevers TJ, Drenth JP. Evaluation of hepatic cystic lesions. World J Gastroenterol. 2013 Jun 21;19(23):3543–54.
32. Spiegel RM, King DL, Green WM. Ultrasonography of primary cysts of the liver. AJR Am J Roentgenol. 1978;131:235–8.
33. Mathieu D, Vilgrain V, Mahfouz A, et al. Benign liver tumors. Magn Reson Imaging Clin N Am. 1997;5:255–88.
34. Ćwik G, Wyroślak-Najs J, Solecki M, Wallner G. Evaluation of the utility value of percutaneous drainage of symptomatic hepatic cysts combined with an obliteration attempt. J Ultrason. 2016;16(66):260–72.
35. Lee S, Seo DW, Paik WH, Park DH, Lee SS, Lee SK, et al. Ethanol lavage of huge hepatic cysts by using EUS guidance and a percutaneous approach. Gastrointest Endosc. 2014;80:1014–21.
36. Herrera JL. Management of hepatic cysts: advances in Hepatology. Gastroenterol Hepatol. 2009;5:414–6.
37. Gamblin TC, Holloway SE, Heckman JT, Geller DA. Laparoscopic resection of benign hepatic cysts: a new standard. J Am Coll Surg. 2008;207:731–6.
38. Erdogan D, van Delden OM, Rauws EA, et al. Results of percutaneous sclerotherapy and surgical treatment in patients with symptomatic simple liver cysts and polycystic liver disease. World J Gastroenterol. 2007;13:3095–100.
39. Moorthy K, Mihssin N, Houghton PW. The management of simple hepatic cysts: sclerotherapy or laparoscopic fenestration. Ann R Coll Surg Engl. 2001;83:409–14.
40. Mazza OM, Fernandez DL, Pekolj J, Pfaffen G, Sanchez Clariá R, Molmenti EP, et al. Management of nonparasitic hepatic cysts. J Am Coll Surg. 2009;209:733–9.
41. Choi CJ, Kim YH, Roh YH, Jung GJ, Seo JW, Baek YH, et al. Management of giant hepatic cysts in the laparoscopic era. J Korean Surg Soc. 2013;85: 116–22.
42. Cheng D, Amin P, Ha TV. Percutaneous sclerotherapy of cystic lesions. Semin Interv Radiol. 2012;29:295–300.
43. van Sonnenberg E, Wroblicka JT, D'Agostino HB, et al. Symptomatic hepatic cysts: percutaneous drainage and sclerosis. Radiology. 1994;190:387–92.
44. Nakaoka R, Das K, Kudo M, Chung H, Innoue T. Percutaneous aspiration and ethanolamine oleate sclerotherapy for sustained resolution of symptomatic polycystic liver disease: an initial experience. AJR Am J Roentgenol. 2009 Dec;193(6):1540–5.
45. Regev A, Reddy KR. Benign solid and cystic tumors of the liver. In: Reddy KR, Long WB, editors. Hepatobiliary tract and pancreas. Edinburgh: Mosby; 2004. p. 189–214.
46. Takei R, Ubara Y, Hosino J, et al. Percutaneous transcatheter hepatic artery embolization for liver cysts in autosomal dominant polycystic kidney disease. Am J Kidney Dis. 2007;49:744–52.
47. Montorsi M, Torzilli G, Fumagalli U, et al. Percutaneous alcohol sclerotherapy of simple hepatic cysts: results from a multicentre survey in Italy. HPB Surg. 1994;8:89–94.
48. Marchal GJ, Desmet VJ, Proesmans WC, et al. Caroli disease: high frequency US and pathologic findings. Radiology. 1986;158:507–11.
49. Pavone P, Laghi A, Catalano C, et al. Caroli's disease: evaluation with MR cholangiopancreatography (MRCP). Abdom Imaging. 1996;21:117–9.
50. Lendoire J, Barros Schelotto P, Alvarez Rodríguez J, et al. Bile duct cyst type V (Caroli's disease): surgical strategy and results. HPB (Oxford). 2007;9(4):281–4.
51. Gillet M, Favre S, Fontolliet C, Halkic N, Mantion G, Heyd B. Monolobar Caroli's disease. Apropos of 12 cases. Chirurgie. 1999;124:13–8.
52. Rose SC, Kumpe DA, Weil R 3rd. Percutaneous biliary drainage in diffuse Caroli's disease (case report). Am J Roentgenol. 1986 Jul;147(1):159–60.

53. Buetow PC, Midkiff RB. Primary malignant neoplasms in the adult. Magn Reson Imaging Clin N Am. 1997;5:289–318.
54. Kim JY, Kim SH, Won Eun H, et al. Differentiation between biliary cystic neoplasms and simple cysts of the liver: accuracy of CT. Am J Roentgenol. 2010;195(5):1142–8.
55. Ariff A, Hassan H, John G. Biliary cystadenoma – computed tomography findings. Malays J Med Sci. 2002;9:49–51.
56. Soares KC, Arnaoutakis DJ, Kamel I, et al. Cystic neoplasms of the liver: biliary cystadenoma and cystadenocarcinoma. J Am Coll Surg. 2014;218(1):119–28.
57. Horsmans Y, Laka A, Gigot JF, Geubel AP. Serum and cystic fluid CA 19-9 determinations as a diagnostic help in liver cysts of uncertain nature. Liver. 1996;16:255–7.
58. Lee JH, Chen DR, Pang SC, Lai YS. Mucinous biliary cystadenoma with mesenchymal stroma: expressions of CA 19-9 and carcinoembryonic antigen in serum and cystic fluid. J Gastroenterol. 1996;31:732–6.
59. Shriki JE, Seyal AR, Dighe MK, et al. CT of Atypical and Uncommon Presentations of Hepatocellular Carcinoma. Am J Roentgenol. 2015;205(4): W411–23.
60. Nagano K, Fukuda Y, Nakano I, et al. An autopsy case of multilocular cystic hepatocellular carcinoma without liver cirrhosis. Hepato-Gastroenterology. 2000;47:1419–21.
61. Gonwa ME, Casillas J, Livingstone AS, Robinson PG. Cystic hepatocellular carcinoma: CT findings. J Comput Assist Tomogr. 1991;15:1045–7.
62. Lewis KH, Chezmar JL. Hepatic metastases. Magn Reson Imaging Clin N Am. 1997;5:319–30.
63. Sugawara Y, Yamamoto J, Yamasaki S, et al. Cystic liver metastases from colorectal cancer. J Surg Oncol. 2000;74:148–52.
64. Singla V, Virmani V, Dey P, Khandelwal N. Solitary giant cystic liver metastasis mimicking an abscess – a word of caution. Indian J Cancer. 2011;48:127–9.
65. Shankar S, vanSonnenberg E, Silverman SG, Tuncali K, Morrison PR. Diagnosis and treatment of intrahepatic biloma complicating radiofrequency ablation of hepatic metastases. Am J Roentgenol. 2003;181:475–7.
66. Stathopoulos V, Georganas M, Stratakis K, Delaporta E, Karallas E, Koutsopoulos K. Hepatic subcapsular biloma: a rare complication of laparoscopic cholecystectomy. Case Rep Surg. 2014;2014:186819.
67. Demeusy A, Hosseini M, Sill AM, Cunningham SC. Intrahepatic pancreatic pseudocyst: a review of the world literature. World J Hepatol. 2016;8(35):1576–83.
68. Mofredj A, Cadranel JF, Dautreaux M, Kazerouni F, Hadj-Nacer K, Deplaix P, Francois G, Danon O, Lukumbo S, Collot G, et al. Pancreatic pseudocyst located in the liver: a case report and literature review. J Clin Gastroenterol. 2000;30:81–3.
69. Guesmi F, Zoghlami A, Saidi Y, Najeh N, Dziri C. Pancreatic pseudocysts located in the liver: a systematic review of the literature. Tunis Med. 2009;87:801–4.

4 Interventions in Pancreatitis: Drainage Procedures

Pankaj Gupta and Pratyaksha Rana

4.1 Introduction

Acute pancreatitis represents acute inflammation of pancreatic parenchyma caused by various etiologies. Gallstone disease and alcohol use are the most common causes [1, 2]. Depending on the etiology, the underlying mechanism leading to pancreatic inflammation is an obstruction to the drainage of pancreatic enzymes or acinar cell destruction. In either case, this leads to autodigestion of pancreatic parenchyma by the pancreatic enzymes. The pancreatic enzymes also invoke a systemic inflammatory response [1]. Revised Atlanta classification provides standardized lexicon for acute pancreatitis [3–5]. According to the revised Atlanta classification, acute pancreatitis is diagnosed in the presence of two of the following three criteria (1) abdominal pain suggestive of pancreatitis (2) serum amylase and lipase levels three times the upper normal value (3) typical radiological features. Contrast-enhanced computed tomography (CECT) is the most commonly used imaging modality. Magnetic resonance imaging (MRI) is an alternative in patients who cannot undergo CECT due to renal dysfunction or concerns regarding radiation exposure [6]. Two phases and three severity grades of acute pancreatitis are recognized, which are essential for prognostication and management (Tables 4.1 and 4.2) [3–6].

Acute pancreatitis is classified into two subcategories based on imaging appearance [3–6]. Acute interstitial pancreatitis is characterized by non-necrotising pancreatic inflammation. It constitutes most of the cases of acute pancreatitis. Acute necrotizing pancreatitis comprises 20% of the cases. It is further subdivided into three types—pancreatic necrosis, peripancreatic necrosis, and both pancreatic and peripancreatic necrosis (most common type). Pancreatic necrosis is characterized by a lack of enhancement or hypoenhancement (attenuation<30 HU) of pancreatic parenchyma [7]. It is challenging to diag-

Table 4.1 Phases of acute pancreatitis

Early phase (first week after onset)	Late phase (after second week of onset-months)
(1) Manifested by systemic inflammatory response (2) Clinical severity and treatment based on type and degree of organ failure	(1) Moderately severe and severe pancreatitis (2) Persistent organ failure and local complications

Table 4.2 Severity of acute pancreatitis

Mild pancreatitis	Moderately severe pancreatitis	Severe pancreatitis
No organ failure or local complications	Transient organ failure (<48 h) or local complications	Organ failure >48 h

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nose pancreatic necrosis within the first 72 h of the onset of acute pancreatitis. Thus, CECT is ideally performed between 5th and 7th days of pain onset [4]. The collections in the setting of acute interstitial pancreatitis contain only fluid and those in the setting of acute necrotizing pancreatitis contain both fluid and necrotic debris (Table 4.3, Fig. 4.1). The most common site for pancreatic collection is retroperitoneum. The lesser sac is the most commonly involved site due to its contiguity with the pancreatic parenchyma [8]. From the lesser sac, the collections may extend to gastrosplenic ligament, perinephric spaces, and paracolic gutters [9]. Though mesenteric inflammation is relatively common, mesenteric collections are less commonly reported [9]. Peritoneal cavity, anterior abdominal wall, and posterior mediastinum are less commonly affected. Rarely the pancreatic collection may extend or rupture into the adjacent organs like liver and spleen [10, 11].

It is vital to diagnose the necrotic component within collections as 90% of acute peripancreatic fluid collections (APFC) resolve within 4 weeks and do not require intervention. Necrotic collections are identified by heterogeneity within the fluid collection or presence of fluid as well as fat attenuation areas within the collection [12]. However, identification as well as quantification of necrotic component may be a challenging task on CT. MRI has higher accuracy in identifying extrapancreatic necrosis [13].

Both necrotic and non-necrotic collections may get infected. Infection of both pancreatic and peripancreatic necrosis increases morbidity and mortality. About one-third of patients with

Table 4.3 Nomenclature of fluid collections in acute pancreatitis

Type of collection	Time after onset of pain (weeks)	Location	Imaging features
Acute peripancreatic fluid collection (AFPC)	≤ 4 weeks	Extrapancreatic	Homogenous, fluid attenuation, no wall
Pseudocyst	>4 weeks	Extrapancreatic	Homogenous, fluid attenuation, circumscribed with wall
Acute necrotic collection (ANC)	≤ 4 weeks	Intra and/or extrapancreatic	Inhomogeneous, non-liquefied component, no wall
Walled-off necrosis (WON)	>4 weeks	Intra and/or extrapancreatic	Inhomogeneous, non-liquefied component, encapsulated with wall

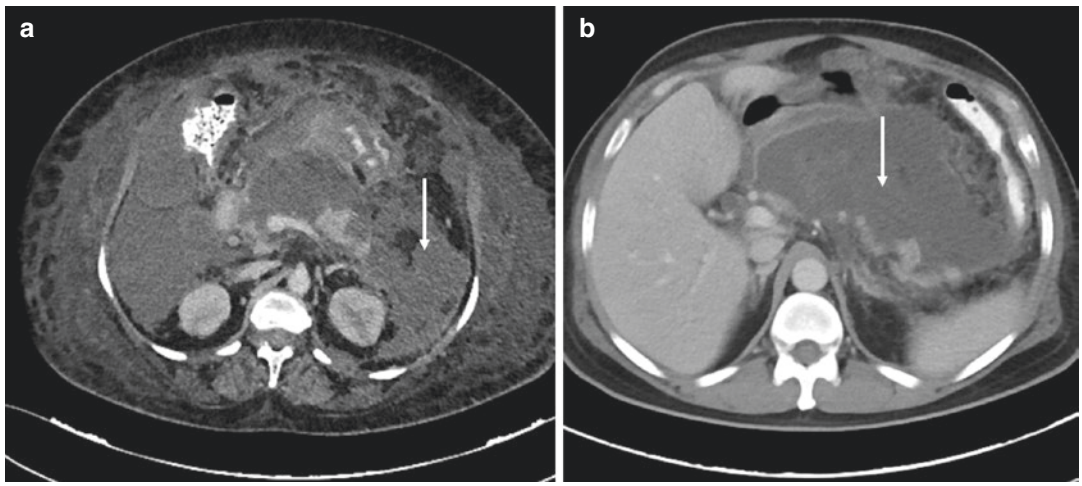

Fig. 4.1 Axial CECT image (**a**) 10 days after onset of pain in a 60-year-old female with gallstone pancreatitis shows acute necrotic collection (arrow). Axial CECT image (**b**) obtained 5 weeks following the pain onset in a 43-year-old man with alcohol-related acute pancreatitis shows a large walled-off necrosis (arrow)

necrosis develop infection. Peak occurrence is after 3–4 weeks but may occur anytime during the disease. Infected collections are essential to diagnose as they invariably require drainage [14]. Clinical deterioration, new or persistent organ failure, and high total leukocyte counts are important clinical signs of infection [1, 14, 15]. Gas within the collection in absence of intervention is a specific sign of infection, although it can also be seen with enteric fistula [3, 4]. Diffusion-weighted imaging, CT perfusion, and positron emission tomography (PET)-CT are newer methods to diagnose infected collections. The volume of necrosis can predict the development of infection. Studies report that if necrosis exceeds 50%, there are higher chances of infection occurring later in the course of the disease [14, 16, 17]. Over time, the clinical relevance of diagnostic aspiration has substantially diminished. It is preferable to obtain cultures at the time of therapeutic drainage rather than to subject patients to diagnostic aspiration due to the fear of iatrogenic infection, false positive, and false negative results [18].

Table 4.4 Indications of drainage of collection in acute pancreatitis

Clinically suspected or documented infected necrosis
Non-resolving organ failure for several weeks or new onset organ failure
Mass effect from collection: pain, gastric outlet obstruction, vascular compression, biliary obstruction, intestinal obstruction, etc.
Disconnected duct syndrome with persistent symptoms
Other: abdominal compartment syndrome, ongoing acute bleeding, bowel ischemia, gastrointestinal fistula

4.2 Management of Acute Pancreatitis

A multidisciplinary approach is key to the successful management of acute pancreatitis [14, 18]. Initial resuscitation, fluid therapy, pain management, supplemental oxygen, and nutritional support are the basic supportive measures provided to all patients with acute pancreatitis. The role of prophylactic antibiotics is controversial [19–21]. Intravenous antibiotics should be administered in cases of suspected or proven infection or when intervention is being planned [22].

Mild acute pancreatitis is usually managed conservatively. Acute peripancreatic fluid collections resolve within 4 weeks and usually do not require intervention. Sterile pancreatic and peripancreatic necrosis are also managed conservatively [23]. Indications of drainage of pancreatic collections are outlined in Table 4.4. Interventions for collections in the setting of acute pancreatitis can be percutaneous, endoscopic, or surgical. In recent years, minimally invasive techniques are more commonly used than conventional open necrosectomy [14, 24]. A classification system of invasive procedures for treating the local complications of acute pancreatitis known as the VRP classification (visualization, route, and purpose) was developed by the Pancreas Network of New Zealand [25].

In this chapter, percutaneous catheter drainage (PCD) of pancreatic collections will be discussed.

4.3 PCD of Pancreatitis Associated Collections

Despite advances in endoscopic and surgical techniques for minimally invasive drainage of pancreatic collections, image-guided PCD remains the most common method of drainage. The advantages of PCD are easy availability and lower cost compared to endoscopic methods. Moreover, being external drainage it can be flushed/irrigated frequently to fecilitate drainage of thick and necrotic collections and can be upsized regularly for optimal drainage of necrotic collections. Compared to surgical techniques, it is less invasive. PCD also provides a gateway for both endoscopic and minimally invasive surgical necrosectomy. Additionally, PCD may be performed in the crtitically ill patients, even at the bedside in intensive care units. Several studies including meta-analysis have shown that the non-operative approach with PCD is successful in up to 50% of patients with infected necrosis [26]. The

Table 4.5 Outcome of PCD for necrotising pancreatitis

Author, Year	No. of patients	Infected necrosis, *n* (%)	Timing of drainage (days after presentation)	Need for necrosectomy, *n* (%)
Lee, 1992 [33]	30	6 (20)	NA	5 (17)
Rotman, 1992 [34]	14	12 (86)	21	11 (79)
Sunday, 1994 [35]	8	0	NA	6 (75)
Aultman, 1997 [36]	19	10 (53)	NA	3 (16)
Freeny, 1998 [27]	34	34 (100)	63 (7 to >300)	18 (53)
Echenique, 1998 [37]	20	20 (100)	NA	0
Gambiez, 1998 [38]	10	3 (30)	17 (10–25)	3 (30)
Fotoohi, 1999 [39]	60	44 (73)	NA	3 (5)
Baril, 2000 [40]	25	19 (76)	NA	7 (18)
Baron, 2002 [41]	38	38 (100)	NA	7 (18)
Cheung, 2005 [42]	8	8 (100)	55 (21–154)	5 (63)
Olah, 2006 [43]	25	15 (60)	12	12 (48)
Navalho, 2006 [44]	30	30 (100)	18	10 (33)
Lee, 2007 [45]	18	18 (100)	10 (1–58)	3 (17)
Szentkereszty, 2008 [46]	61	NA	>28	15 (25)
Bruennler, 2008 [47]	80	80 (100)	>15	24 (30)
Mortele, 2009 [48]	35	35 (100)	11[a] (2–33)	13 (37)
Rocha, 2009 [58]	28	9 (32)	NA	17 (61)
Van santvoort, 2010 [49]	43	43 (100)	30[b] (11–71)	26 (60)
Sugimoto, 2015 [50]	47	17 (36)	22 (2–73)	0
Sugimoto, 2016 [51]	39	12 (31)	23	0
Mallick, 2018 [52]	375	214 (57)	NA	50 (13.3)
Bellam, 2019 [53]	51	11 (21.56)	20	4 (7.8)

NA-not available, [a]Mean, [b]Median. Modified from freeman et al. [14]

overall mortality rate is lower in patients who undergo PCD. Freeny et al. first described the preferential treatment of infected pancreatic necrosis using PCD in 34 patients and reported a clinical success rate of 47% with PCD alone [27]. Since then, many studies have shown a high success rate of PCD in acute pancreatitis [26–32]. The outcome of PCD for necrotizing pancreatitis is summarized in Tables 4.5 and 4.6 [33–53, 58]. A step-up approach comprising of initial percutaneous or endoscopic drainage followed by minimally invasive necrosectomy has been found to improve the outcomes in patients with acute pancreatitis [49, 59–61]. The PANTER trial by the Dutch pancreatitis group popularized the step-up approach [49]. In this trial, among the patients with infected pancreatic necrosis assigned to the step-up protocol, one-third could be treated with PCD alone. The step-up approach comprising initial PCD reduced the mortality as well as the rate of major complications compared to open necrosectomy.

Endoscopic drainage of pancreatic collections is a minimally invasive procedure. The advances in endoscopic techniques have increased the interest and applications of this procedure. Bakker et al., in their randomized control trial compared the efficacy of endoscopic necrosectomy and surgical necrosectomy in 22 patients and found a lower post-procedure inflammatory response, complication rate, lesser pancreatic fistula development and lesser endocrine and exocrine deficiency in patients with endoscopic drainage [62].

Various studies have compared percutaneous with endoscopic drainage [63–65]. The disadvantages with the use of percutaneous drainage are external catheters which compromise the quality of life and localized skin complication. Additionally, larger stents and drains can be placed with endoscopic drainage, which allows better drainage of heterogeneous collection. The drainage with endoscopic route is more physiological with lesser loss of pancreatic fluid.

Table 4.6 Studies reporting outcome of PCD in sterile fluid collection

Author, Year	Number	Success	Surgery	Mortality	Remarks
Walser, 2006 [54]	22	NA	4 (22%)	2 (9.1%)	Increased risk of catheter infection
Mortele, 2009 [48]	22	11 (50%)	6 (27.3%)	5 (22.7%)	High mortality due to MOF at baseline
Zerem, 2009 [54]	20	17 (85%)	3 (15%)	1 (5%)	11 patients had secondary infection
Kotan, 2015 [55]	4	4 (40%)	6 (60%)	1 (10%)	PCD resulted in decrease in CRP level
Wang, 2016 [56]	248	NA	21 (8.6%)	27 (10.9%)	None

NA-not available, MOF-multiorgan failure, CRP-C-reactive protein. Modified from Sharma et al. [57]

However, general anesthesia may be required for endoscopic drainage, whereas percutaneous drainage can be done under local anesthesia and even at bedside in critically ill patients. In a study by Keane et al. endoscopic drainage of symptomatic pancreatic fluid collection was associated with a higher rate of treatment success, a lower rate of reintervention, and shorter hospital stay [63]. Khan et al. [64] in their meta-analysis also found similar results with the superiority of endoscopic versus percutaneous drainage.

4.4 Timing of Percutaneous Drainage

Acute sterile collections early in the course of the disease seldom require intervention and are managed conservatively. Similarly, patients with acute collections with clinical deterioration, persistent systemic inflammatory response syndrome, and multiorgan failure with no features of infection are managed conservatively. Early invasive interventions have been shown to be associated with a risk of bleeding and perforation of adjacent hollow viscus [65–67]. Later in the course of the disease, when the collection gets encapsulated, intervention may be required in cases of symptoms or obstructive features (Table 4.4). Infected acute necrotic collections may require intervention early in the course of the disease. The preferred method is PCD. Abdominal compartment syndrome requires decompression early in the course of the disease, which can be done by both surgical and percutaneous route. Infected walled-off necrosis with at least partial liquefaction and encapsulation more than 4–6 weeks after the onset of the disease require intervention, especially when symptomatic. There is evidence that delayed intervention is superior to early intervention in terms of reduced morbidity and mortality [65–67]. The current recommendation to postpone interventions until 4 weeks after the start of the disease were formulated from studies on primary open surgical necrosectomy. As currently drainage is employed as the first intervention in step-up approach, postponement of catheter drainage until encapsulation might not be necessary. However, robust clinical data is lacking in this aspect. Grinsven et al. did a systematic review of the timing of catheter drainage in patients with infected collections [68]. Early catheter drainage of the symptomatic fluid collection can lead to the removal of pancreatic necrotic and/or infected tissue and decrease intra-abdominal pressure resulting in interruption of the inflammatory cascade. A recent study by Mallick et al. comprising 258 patients with ANC and 117 patients with WON reported that early PCD is as efficient and safe as delayed PCD [52]. Postponed versus immediate drainage of infected necrotizing pancreatitis (POINTER trial) is a randomized control trial being undertaken to investigate whether immediate catheter drainage in infected necrotizing pancreatitis reduces the risk of complications as compared with the current protocol of delaying intervention until the stage of walled-off necrosis [69].

4.5 Image Guidance

PCD of pancreatic collections can be performed under ultrasound or CT guidance. Ultrasound is easily available, inexpensive, and radiation-free modality in which real-time needle placement can be done. Ultrasound-guided PCD may be performed even at the bedside in intensive care units. However, since the pancreas is a retroperitoneal organ, some of the collections are not well visualized and may not be amenable to drainage under ultrasound guidance. Deeper collections are better accessed with CT guidance. With CT fluoroscopy, real-time placement of the needle is feasible. Fusion techniques, including ultrasound/CT image fusion achieve a higher technical success rate [70]. Upgradation of the catheter can be done under ultrasound, CT, or fluoroscopic guidance. The feasibility of MRI guided percutaneous catheter drainage of pancreatic collections has also been reported [71].

4.6 Drainage Procedure

4.6.1 Pre-Procedure Evaluation and Planning of the Procedure

CECT is available before PCD in most patients. However, in some patients, especially those with acute kidney injury, PCD may be planned with ultrasound alone. Proper assessment of collection site, size, character, relationship with adjacent organs, and vessels is critical. Coagulation profile and hemogram of the patient are assessed and optimized (platelet count >50,000/μl and INR < 1.5). Informed written consent of the patient is obtained. Hardware required for PCD is listed in Table 4.7 and shown in Fig. 4.2. Strict sterile conditions should be maintained during each step of the procedure. Equipment for monitoring and resuscitation must be available at the time of the procedure. PCD is feasible under local anesthesia in most of the patients. Analgesics, antispasmodics, and antiemetics may be required based on the patients' condition.

Table 4.7 Hardware required for PCD of pancreatic collections

18G needle
Stiff guidewire (0.035 inch)
Set of dilators
Catheter pigtail or Malecot or self-locking catheter
Other suture material, dressing.

4.6.2 Technique of Catheter Placement

The two primary techniques of PCD anywhere in the body are the trocar technique and the Seldinger technique. The former is a single-step technique. Though it is a faster method, it has the potential for complications. A relatively smaller catheter may be inserted using this technique. Seldinger technique involves multiple steps, involving the introduction of a needle, followed by placement of a guidewire and dilatation of the access tract (Fig. 4.3). Finally, the desired catheter is placed over the guidewire. Seldinger technique is the preferred method for drainage of pancreatic collections. Though there are no standard recommendations regarding the initial catheter size, most of the expert interventional radiologists involved in the care of patients with acute pancreatitis agree that a larger bore catheter should be used. In the authors' interventional radiology unit, 14 Fr catheter is routinely used for initial PCD. Following the initial PCD, upsizing of the catheter is required to allow drainage of necrotic debris. The final catheter size may be as large as 30–48 Fr. Smaller size catheters are used for drainage of liquefied collections having no/ little solid necrotic material, pancreatic ascites, and pleural effusion. The large-bore and multiple catheters are required for heterogeneous collections with solid necrotic material (Fig. 4.4). In a retrospective study by Bruennler et al. there was no change in outcome in patients with infected pancreatic necrosis depending on the initial size of the catheter [47]. However, prospective randomized studies are required to prove this.

In recent years, there have been several reports on proactive drainage of pancreatic collections. A

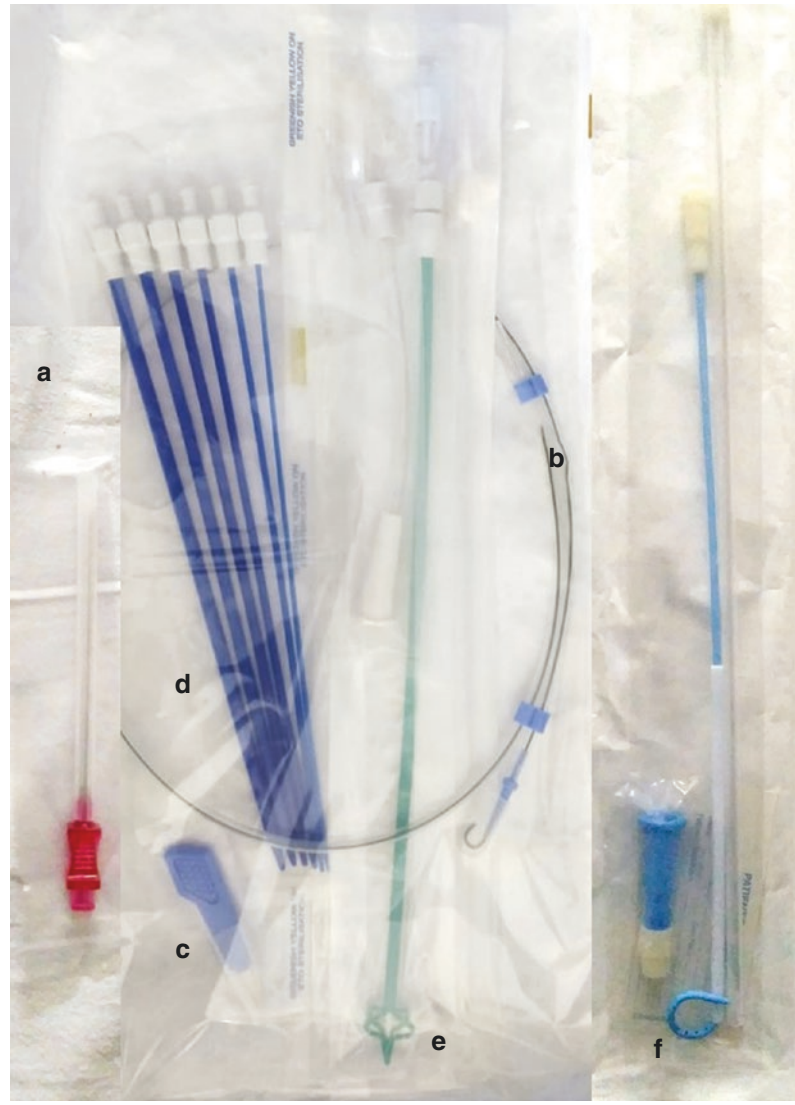

Fig. 4.2 Hardware for percutaneous drainage of pancreatic collections. (**a**) 18G needle; (**b**) Stiff 0.035″ guidewire, (**c**) Blade, (**d**) Fascial dilators, (**e**) Malecot catheter, (**f**) Pigtail catheter

proactive protocol involves more frequent upsizing of the catheters with the aim to drain the entire collection, including the liquid component as well as the necrotic debris. In the study by Grinsven et al. 117 patients with infected necrosis underwent PCD: 42 patients with proactive protocol and 75 patients with a standard protocol [72]. The authors reported a reduced need for necrosectomy in patients undergoing proactive PCD. Sugimoto et al. also reported a reduced need for necrosectomy, low incidences of organ failure, and reduced mortality in the proactive protocol [51].

4.6.3 Approach for Percutaneous Drainage of Pancreatic Collections (Site and Route)

Most direct, shortest path for drainage should be used. Vital organs should be avoided. The route will depend on the site, size, extent of the collection, and relationship with adjacent organs. The placement of the catheter should be comfortable to the patient, not hampering day to day necessary activities. The following routes may be utilized for PCD of pancreatic collections (Figs. 4.5 and 4.6).

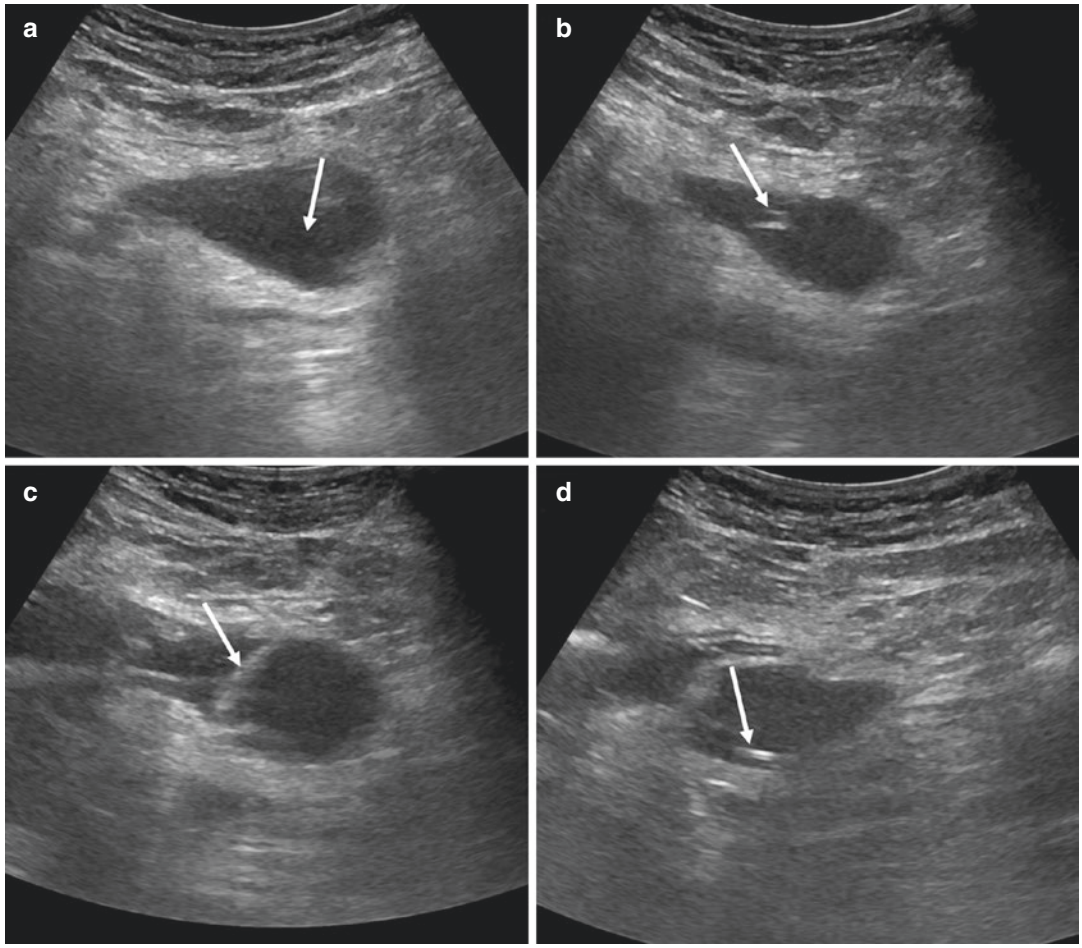

Fig. 4.3 Seldinger technique for ultrasound-guided PCD of pancreatic fluid collection. (**a**) Fluid collection is seen in lesser sac (arrow). (**b**) Ultrasound-guided needle (arrow) insertion is performed. (**c**) A guidewire (arrow) is placed through the needle. (**d**) After the tract is serially dilated using fascial dilators (6–14 Fr), 14Fr pigtail catheter is inserted into the collection (arrow)

1. Retroperitoneal route
2. Transperitoneal route
3. Transgastric route
4. Transhepatic route

The organs to be avoided are bowel loops, spleen, and gallbladder. Retroperitoneal access via the left posterolateral approach between the left kidney and colon is preferred as the catheter can be placed along the long axis of the collection [73].

Additionally, this approach allows for minimally invasive surgical necrosectomy. In a study by Horvath et al. video assisted retroperitoneal debridement (VARD) was found to be feasible in 60% of the patients requiring surgical treatment [74]. In more than three-fourths of the patients, open necrosectomy was not required. VARD was used as the standard approach for necrosectomy in the landmark PANTER trial [49]. The transperitoneal route should be used when there is no safe window for retroperitoneal drainage. With the increasing utilization of endoscopic drainage, transgastric route for drainage of pancreatic collections is less commonly employed [75, 76]. However, in patients who are not candidates for retroperitoneal or transperitoneal drainage, especially patients in the intensive care unit may benefit from trans-

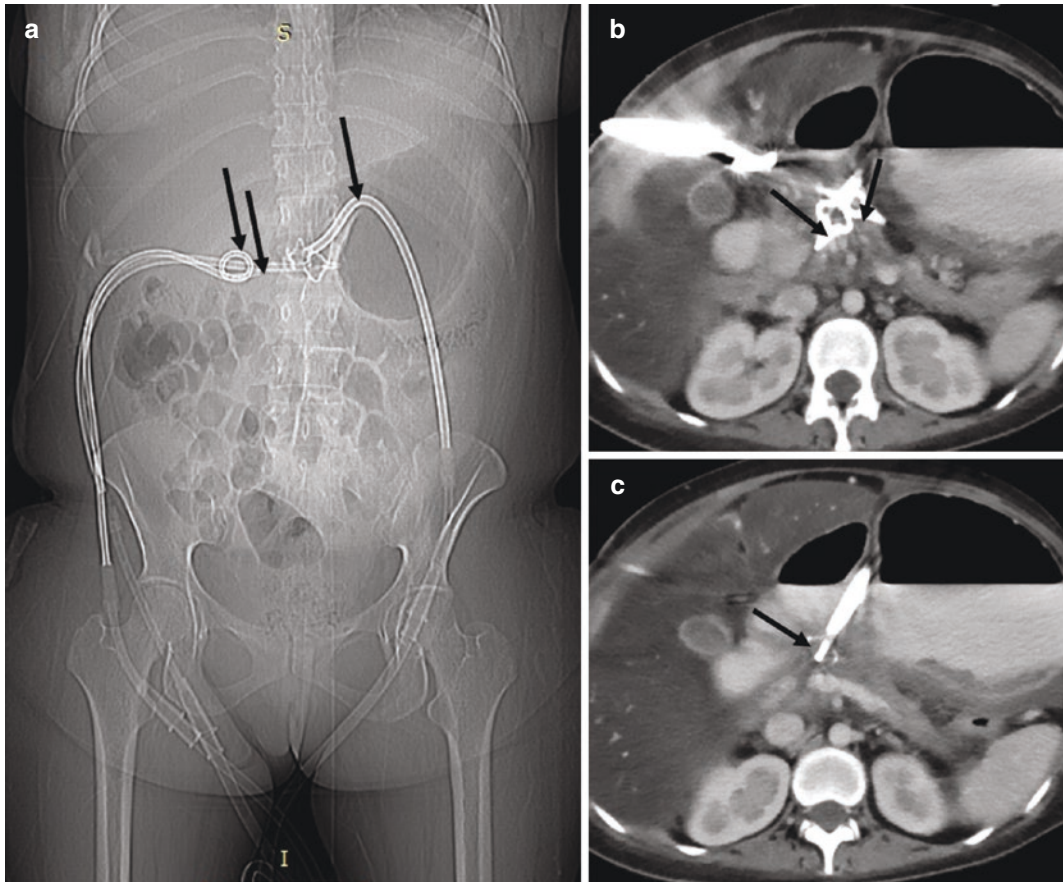

Fig. 4.4 CT scanogram (**a**) in a 32-year-old female with gallstone pancreatitis (pot-necrosectomy status) shows multiple (three) catheters in the peripancreatic location (arrows). Axial CT images (**b** and **c**) show multiple large-bore Malecot catheters in the lesser sac (arrows)

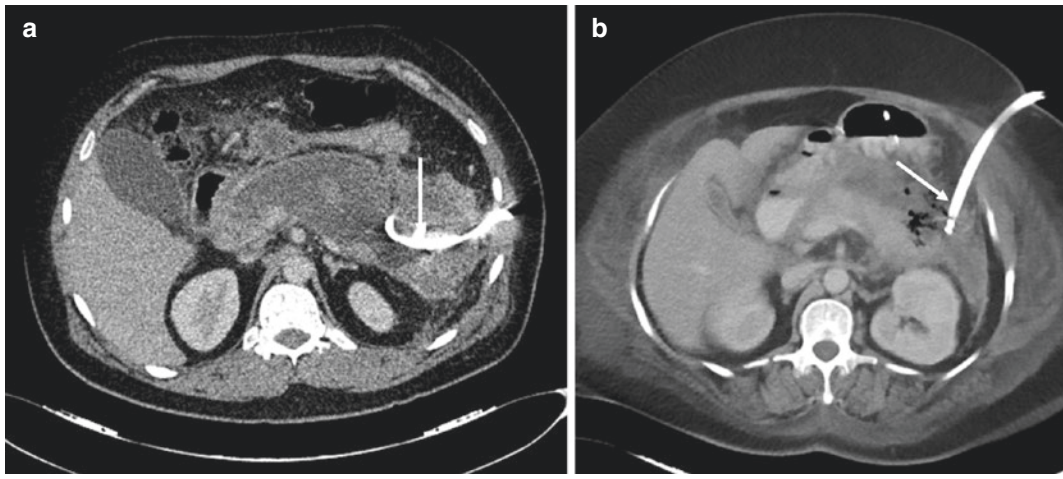

Fig. 4.5 (**a**) Retroperitoneal catheter insertion along the long axis of the pancreatic collection was performed under CT guidance (arrow). (**b**) A transperitoneal catheter was inserted in this peripancreatic collection under CT guidance (arrow)

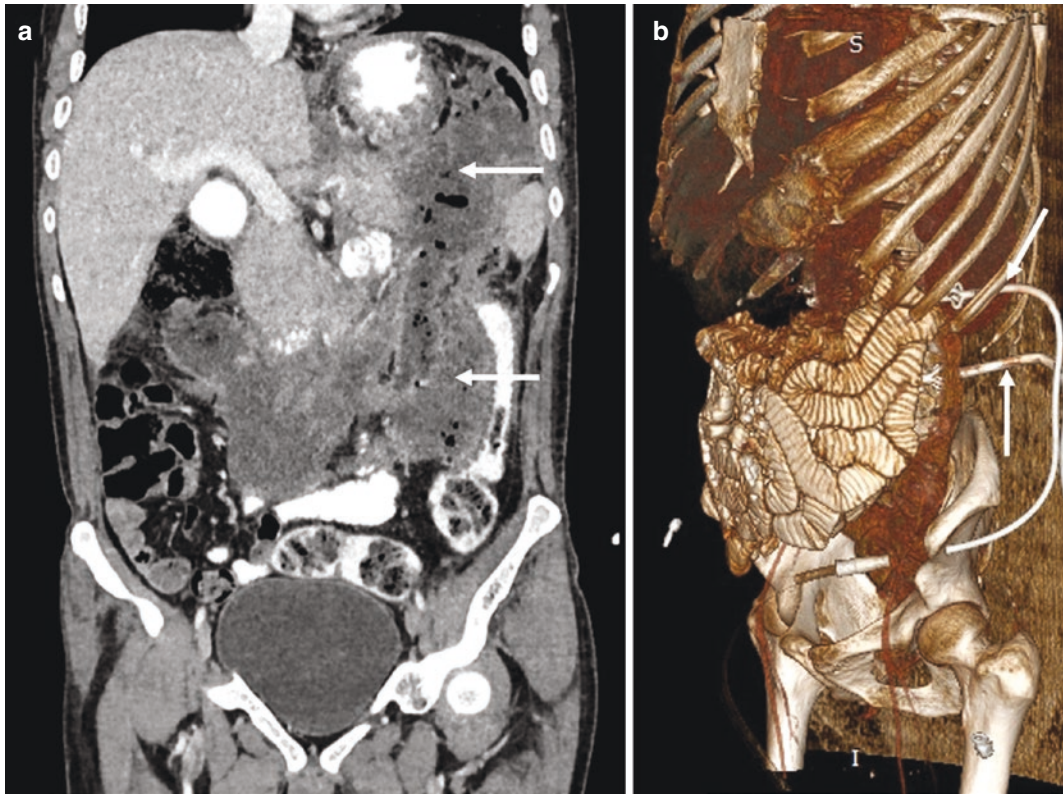

Fig. 4.6 (**a**) Coronal reformatted CECT image shows an extensive left paracolic gutter collection (arrows). (**b**) Two percutaneous catheters were placed into the collection via the retroperitoneal approach (arrows)

gastric drainage. The transhepatic route has been described for inaccessible lesser sac fluid collections. In the published studies on the transhepatic drainage of intra-abdominal abscesses and fluid collections in the postoperative setting, 100% technical success and no significant complications have been reported [77, 78].

4.6.4 Catheter Management

1. Proper dressing and suturing of the catheter should be done to prevent dislodgement. Locking catheters can be used to avoid dislodgement.
2. Active flushing: Gravity drainage of the collection with regular flushing with normal saline should be done.
3. Exchange: Because of the solid debris, the catheters get frequently blocked. Upsizing is needed to allow continued drainage of the collection.
4. Repositioning of catheter in case of displacement or dislodgement.
5. Additional catheter: if there is no improvement even after 72 h of initial PCD, imaging is done to identify residual or new collection for other PCD.
6. Adequate local hygiene should be maintained to prevent superadded infections and cellulitis.

The decision to remove the catheter and stop the drainage is usually a multidisciplinary decision based on clinical improvement (control of sepsis, resolution of fever, hemodynamic stability, and relief of pressure symptoms), improvement of laboratory parameters (total leucocyte counts, decrease in CRP and procalcitonin levels) and radiological improvement (reduction in the size of collection) with drainage less than 20 mL/day at least for two or three consecutive days [57].

4.7 Complications of Catheter Placement

1. Local site complications (cellulitis, scar formation): local hygiene prevents or reduces the severity of these complications.
2. External pancreatic fistula (EPF): it is defined as the drainage of clear pancreatic secretions of greater than 100 mL/ day beyond 3 weeks of catheter insertion [79]. A majority of EPFs can be managed conservatively. However, in the case of refractory EPF, pancreatic stenting is required.
3. Blockade of catheter: regular saline flushing helps prevent catheter blockade. However, catheter upsizing is frequently required to prevent/ treat this event.
4. Slippage of catheter: it requires reinsertion of the catheter if there is a residual collection and patient is symptomatic.
5. Bleeding from catheter: it may be related to a vascular injury secondary to catheter insertion or vascular damage induced by pancreatic enzymes in the course of severe acute necrotizing pancreatitis. A CT angiography is performed to investigate the cause of bleed from the percutaneous catheter. Arterial pseudoaneurysm is one of the most significant complication causing bleeding from the catheter. It is managed effectively with endovascular embolization [80].
6. Fistulous communication with bowel loop: It can be iatrogenic. However, more commonly, it is the result of inflammation/ ischemia of the bowel wall resulting from the effect of pancreatic secretion. The most common site for bowel fistulisation is the colon [81]. Other common sites are stomach and duodenum. The fistulisation with the upper GI tract may be managed conservatively while the colonic fistula requires surgical management [82]. However, recent literature suggests that some colonic fistulae may be managed conservatively. Other methods described for the management of colonic fistulae are over the scope clips and stents.

4.8 Factors Predictive of the Outcome of PCD

It is essential to predict which patients are going to benefit from PCD. Several predictive factors, including the presence of multiorgan failure, non-liquefied necrotic collections with higher CT density, the volume of the collection, etc. have been described to predict the outcome of PCD [48, 54–56, 83–89]. The studies reporting these factors are summarized in Tables 4.7 and 4.8.

Table 4.8 Predictors of outcome of PCD in patients with pancreatic necrosis

Author, year	Number	Success	Necrosectomy/ Further intervention	Mortality	Predictors
Predictors of failure					
Babu, 2013 [86]	56	26 (26.4%)	27 (48%)	16 (28.5%)	Renal failure, APACHE II score at first intervention and number of bacteria isolated
Hollemans, 2016 [83]	130	45 (35%)	76 (58.5%)	26 (20%)	Male gender, MOF, pancreatic necrosis amount, heterogeneous collection
Guo, 2016 [84]	51	35 (68.6%)	16 (31.3%)	3 (6%)	Higher CT density of collection
Li, 2016 [85]	54	18 (33.3%)	32 (59.3%)	4 (9.3%)	Heterogenous collections, multiple infected collections, higher CTSI
Predictors of success					
Bellam, 2019 [53]	51	34 (66.6%)	4 (7.84%)	15 (29.4%)	Percentage reduction of volume of collection, organ failure resolution

MOF-multiorgan failure. Modified from Sharma et al. [57]

References

1. Pandol SJ, Saluja AK, Imrie CW, Banks PA. Acute pancreatitis: bench to the bedside. Gastroenterology. 2007;132(3):1127–51.
2. Shanbhogue AK, Fasih N, Surabhi VR, Doherty GP, Shanbhogue DK, Sethi SK. A clinical and radiologic review of uncommon types and causes of pancreatitis. Radiographics. 2009;29(4):1003–26.
3. Banks PA, Bollen TL, Dervenis C, Acute Pancreatitis Classification Working Group, et al. Classification of acute pancreatitis--2012: revision of the Atlanta classification and definitions by international consensus. Gut. 2013;62(1):102–11.
4. Foster BR, Jensen KK, Bakis G, Shaaban AM, Coakley FV. Revised Atlanta classification for acute pancreatitis: a pictorial essay. Radiographics. 2019;39(3):912.
5. Thoeni RF. The revised Atlanta classification of acute pancreatitis: its importance for the radiologist and its effect on treatment. Radiology. 2012;262(3):751–64.
6. Gupta P, Jain R, Koshi S, et al. Radiation dose from computed tomography in patients with acute pancreatitis: an audit from a tertiary care referral hospital. Abdom Radiol (NY). 2020;45(5):1517–23.
7. Balthazar EJ. CT contrast enhancement of the pancreas: patterns of enhancement, pitfalls and clinical implications. Pancreatology. 2011;11:585–7.
8. Ishikawa K, Idoguchi K, Tanaka H, et al. Classification of acute pancreatitis based on retroperitoneal extension: application of the concept of interfascial planes. Eur J Radiol. 2006;60(3):445–52.
9. Gupta P, Rana P, Bellam BL, et al. Site and size of extrapancreatic necrosis are associated with clinical outcomes in patients with acute necrotizing pancreatitis. Pancreatology. 2020;20(1):9–15.
10. Mortelé KJ, Mergo PJ, Taylor HM, Ernst MD, Ros PR. Splenic and perisplenic involvement in acute pancreatitis: determination of prevalence and morphologic helical CT features. J Comput Assist Tomogr. 2001;25(1):50–4.
11. Gupta P, Virk M, Gulati A, et al. Unusual sites of necrotic collections in acute necrotizing pancreatitis: association with parenchymal necrosis and clinical outcomes. Dig Dis Sci 2020. https://doi.org/10.1007/s10620-020-06526-6 (Ahead of Print).
12. Wang M, Wei A, Guo Q, et al. Clinical outcomes of combined necrotizing pancreatitis versus extrapancreatic necrosis alone. Pancreatology. 2016;16(1):57–65.
13. Morgan DE, Baron TH, Smith JK, Robbin ML, Kenney PJ. Pancreatic fluid collections prior to intervention: evaluation with MR imaging compared with CT and US. Radiology. 1997;203(3):773–8.
14. Freeman ML, Werner J, van Santvoort HC, et al. International Multidisciplinary Panel of Speakers and Moderators. Interventions for necrotizing pancreatitis: summary of a multidisciplinary consensus conference. Pancreas. 2012;41(8):1176–94.
15. Rau BM, Bothe A, Kron M, Beger HG. Role of early multisystem organ failure as major risk factor for pancreatic infections and death in severe acute pancreatitis. Clin Gastroenterol Hepatol. 2006;4(8):1053–61.
16. Gerzof SG, Banks PA, Robbins AH, et al. Early diagnosis of pancreatic infection by computed tomography-guided aspiration. Gastroenterology. 1987;93:1315–20.
17. Banks PA, Gerzof SG, Chong FK, et al. Bacteriologic status of necrotic tissue in necrotizing pancreatitis. Pancreas. 1990;5:330–3.
18. Working Group IAP/APA Acute Pancreatitis Guidelines. IAP/APA evidence-based guidelines for the management of acute pancreatitis. Pancreatology. 2013;13(4 Suppl 2):e1–15.
19. Wittau M, Mayer B, Scheele J, Henne-Bruns D, Dellinger EP, Isenmann R. Systematic review and meta-analysis of antibiotic prophylaxis in severe acute pancreatitis. Scand J Gastroenterol. 2011;46(3):261–70.
20. Jiang K, Huang W, Yang XN, Xia Q. Present and future of prophylactic antibiotics for severe acute pancreatitis. World J Gastroenterol. 2012;18:279e84.
21. Villatoro E, Mulla M, Larvin M. Antibiotic therapy for prophylaxis against infection of pancreatic necrosis in acute pancreatitis. Cochrane Database Syst Rev. 2010;5:CD002941.
22. Piascik M, Rydzewska G, Milewski J, et al. The results of severe acute pancreatitis treatment with continuous regional arterial infusion of protease inhibitor and antibiotic: a randomized controlled study. Pancreas. 2010;39:863e7.
23. Büchler MW, Gloor B, Müller CA, Friess H, Seiler CA, Uhl W. Acute necrotizing pancreatitis: treatment strategy according to the status of infection. Ann Surg. 2000;232(5):619–26.
24. Bello B, Matthews JB. Minimally invasive treatment of pancreatic necrosis. World J Gastroenterol. 2012;18(46):6829–35.
25. Loveday BP, Petrov MS, Connor S, Rossaak JI, Mittal A, Phillips AR, et al. Pancreas Network of New Zealand. A comprehensive classification of invasive procedures for treating the local complications of acute pancreatitis based on visualization, route, and purpose. Pancreatology. 2011;11(4):406–13.
26. Zhang ZH, Ding YX, Wu YD, Gao CC, Li F. A meta-analysis and systematic review of percutaneous catheter drainage in treating infected pancreatitis necrosis. Medicine. 2018;97(47):e12999.
27. Freeny PC, Hauptmann E, Althaus SJ, Traverso LW, Sinanan M. Percutaneous CT-guided catheter drainage of infected acute necrotizing pancreatitis: techniques and results. AJR Am J Roentgenol. 1998;170(4):969–75.
28. Baudin G, Chassang M, Gelsi E, et al. CT-guided percutaneous catheter drainage of acute infectious necrotizing pancreatitis: assessment of effectiveness and safety. AJR Am J Roentgenol. 2012;199(1):192–9.
29. Mehta V, Kumar R, Parkash S, et al. Role of percutaneous catheter drainage as primary treatment

of necrotizing pancreatitis. Turk J Gastroenterol. 2019;30(2):184–7.
30. Ke L, Li J, Hu P, Wang L, Chen H, Zhu Y. Percutaneous catheter drainage in infected pancreatitis necrosis: a systematic review. Indian J Surg. 2016;78(3): 221–8.
31. van Baal MC, van Santvoort HC, Bollen TL, Bakker OJ, Besselink MG, Gooszen HG, Dutch Pancreatitis Study Group. Systematic review of percutaneous catheter drainage as primary treatment for necrotizing pancreatitis. Br J Surg. 2011;98(1):18–27.
32. Uhl W. Systematic review of percutaneous catheter drainage as primary treatment for necrotizing pancreatitis. Br J Surg. 2011;98(1):27–8.
33. Lee MJ, Rattner DW, Legemate DA, et al. Acute complicated pancreatitis: redefining the role of interventional radiology. Radiology. 1992;183(1):171–4.
34. Rotman N, Mathieu D, Anglade MC, Fagniez PL. Failure of percutaneous drainage of pancreatic abscesses complicating severe acute pancreatitis. Surg Gynecol Obstet. 1992;174(2):141–4.
35. Sunday ML, Schuricht AL, Barbot DJ, Rosato FE. Management of infected pancreatic fluid collections. Am Surg. 1994;60(1):63–7.
36. Aultman DF, Bilton BD, Zibari GB, McMillan RW, McDonald JC. Non-operative therapy for acute necrotizing pancreatitis. Am Surg. 1997;63(12):1114–7.
37. Echenique AM, Sleeman D, Yrizarry J, et al. Percutaneous catheter-directed debridement of infected pancreatic necrosis: results in 20 patients. J Vasc Interv Radiol. 1998;9(4):565–71.
38. Gambiez LP, Denimal FA, Porte HL, Saudemont A, Chambon JP, Quandalle PA. Retroperitoneal approach and endoscopic management of peripancreatic necrosis collections. Arch Surg. 1998;133(1):66–72.
39. Fotoohi M, D'Agostino HB, Wollman B, Chon K, Shahrokni S, van Sonnenberg E. Persistent pancreatocutaneous fistula after percutaneous drainage of pancreatic fluid collections: role of cause and severity of pancreatitis. Radiology. 1999;213(2):573–8.
40. Baril NB, Ralls PW, Wren SM, et al. Does an infected peripancreatic fluid collection or abscess mandate operation? Ann Surg. 2000;231(3):361–7.
41. Baron TH, Harewood GC, Morgan DE, Yates MR. Outcome differences after endoscopic drainage of pancreatic necrosis, acute pancreatic pseudocysts, and chronic pancreatic pseudocysts. Gastrointest Endosc. 2002;56(1):7–17.
42. Cheung MT, Ho CN, Siu KW, Kwok PC. Percutaneous drainage and necrosectomy in the management of pancreatic necrosis. ANZ J Surg. 2005;75(4):204–7.
43. Oláh A, Belágyi T, Bartek P, Pohárnok L, Romics L Jr. Alternative treatment modalities of infected pancreatic necrosis. Hepato-Gastroenterology. 2006;53(70):603–7.
44. Navalho M, Pires F, Duarte A, Gonçalves A, Alexandrino P, Távora I. Percutaneous drainage of infected pancreatic fluid collections in critically ill patients: correlation with C-reactive protein values. Clin Imaging. 2006;30(2):114–9.
45. Lee JK, Kwak KK, Park JK, et al. The efficacy of nonsurgical treatment of infected pancreatic necrosis. Pancreas. 2007;34(4):399–404.
46. Szentkereszty Z, Kotán R, Pósán J, Arkossy P, Sápy P. Therapeutic tactics in the treatment of acute necrotizing pancreatitis. Hepato-Gastroenterology. 2008;55(81):266–9.
47. Bruennler T, Langgartner J, Lang S, et al. Outcome of patients with acute, necrotizing pancreatitis requiring drainage-does drainage size matter? World J Gastroenterol. 2008;14(5):725–30.
48. Mortelé KJ, Girshman J, Szejnfeld D, et al. CT-guided percutaneous catheter drainage of acute necrotizing pancreatitis: clinical experience and observations in patients with sterile and infected necrosis. AJR Am J Roentgenol. 2009;192(1):110–6.
49. Van Santvoort HC, Besselink MG, Bakker OJ, Dutch Pancreatitis Study Group, et al. A step-up approach or open necrosectomy for necrotizing pancreatitis. N Engl J Med. 2010;362(16):1491–502.
50. Sugimoto M, Sonntag DP, Flint GS, et al. A percutaneous drainage protocol for severe and moderately severe acute pancreatitis. Surg Endosc. 2015;29(11):3282–91.
51. Sugimoto M, Sonntag DP, Flint GS, et al. Better outcomes if percutaneous drainage is used early and proactively in the course of necrotizing pancreatitis. J Vasc Interv Radiol. 2016;27(3):418–25.
52. Mallick B, Dhaka N, Gupta P, et al. An audit of percutaneous drainage for acute necrotic collections and walled off necrosis in patients with acute pancreatitis. Pancreatology. 2018;18(7):727–33.
53. Bellam BL, Samanta J, Gupta P, et al. Predictors of outcome of percutaneous catheter drainage in patients with acute pancreatitis having acute fluid collection and development of a predictive model. Pancreatology. 2019;S1424-3903(19):30580.
54. Zerem E, Imamovic G, Omerović S, Imširović B. Randomized controlled trial on sterile fluid collections management in acute pancreatitis: should they be removed? Surg Endosc. 2009;23(12):2770–7.
55. Kotán R, Sápy P, Sipka S, et al. Serum C-reactive protein and white blood cell level as markers of successful percutaneous drainage of acute sterile peripancreatic fluid collection. Chirurgia. 2015;110(1):56–9.
56. Wang T, Liu LY, Luo H, et al. Intra-abdominal pressure reduction after percutaneous catheter drainage is a protective factor for severe pancreatitis patients with sterile fluid collections. Pancreas. 2016;45(1):127–33.
57. Sharma V, Gorsi U, Gupta R, Rana SS. Percutaneous interventions in acute necrotizing pancreatitis. Trop Gastroenterol. 2016;37(1):4–18.
58. Rocha FG, Benoit E, Zinner MJ, et al. Impact of radiologic intervention on mortality in necrotizing pancreatitis: the role of organ failure. Arch Surg. 2009;144(3):261–5.
59. Sion MK, Davis KA. Step-up approach for the management of pancreatic necrosis: a review of the literature. Trauma Surg Acute Care Open. 2019;4(1):e000308.

60. Strobel O, Büchler MW. Necrotizing pancreatitis: long-term outcomes show superiority of the step-up approach versus open necrosectomy. Chirurg. 2019;90(2):153.
61. Hollemans RA, Bakker OJ, Boermeester MA, Dutch Pancreatitis Study Group, et al. Superiority of step-up approach vs open necrosectomy in long-term follow-up of patients with necrotizing pancreatitis. Gastroenterology. 2019;156(4):1016–26.
62. Bakker OJ, van Santvoort HC, van Brunschot S, Dutch Pancreatitis Study Group, et al. Endoscopic transgastric vs surgical necrosectomy for infected necrotizing pancreatitis: a randomized trial. JAMA. 2012;307(10):1053–61.
63. Keane MG, Sze SF, Cieplik N, et al. Endoscopic versus percutaneous drainage of symptomatic pancreatic fluid collections: a 14-year experience from a tertiary hepatobiliary centre. Surg Endosc. 2016;30(9):3730–40.
64. Khan MA, Hammad T, Khan Z, et al. Endoscopic versus percutaneous management for symptomatic pancreatic fluid collections: a systematic review and meta-analysis. Endosc Int Open. 2018;6(4):E474–83.
65. Fernandez-del Castillo C, Rattner DW, Makary MA, Mostafavi A, McGrath D, Warshaw AL. Debridement and closed packing for the treatment of necrotizing pancreatitis. Ann Surg. 1998;228:676e84.
66. Besselink MG, Verwer TJ, Schoenmaeckers EJ, et al. Timing of surgical intervention in necrotizing pancreatitis. Arch Surg. 2007;142:1194e201.
67. Mier J, Luque-de León E, Castillo A, Robledo F, Blanco R. Early versus late necrosectomy in severe necrotizing pancreatitis. Am J Surg. 1997;173:71e5.
68. Van Grinsven J, van Santvoort HC, Boermeester MA, Dutch Pancreatitis Study Group, et al. Timing of catheter drainage in infected necrotizing pancreatitis. Nat Rev Gastroenterol Hepatol. 2016;13(5):306–12.
69. Van Grinsven J, Van Dijk SM, Dijkgraaf MG, Dutch Pancreatitis Study Group, et al. Postponed or immediate drainage of infected necrotizing pancreatitis (POINTER trial): study protocol for a randomized controlled trial. Trials. 2019;20(1):239.
70. Zhang H, Chen GY, Xiao L, et al. Ultrasonic/CT image fusion guidance facilitating percutaneous catheter drainage in treatment of acute pancreatitis complicated with infected walled-off necrosis. Pancreatology. 2018;18(6):635–41.
71. Kariniemi J, Sequeiros RB, Ojala R, Tervonen O. Feasibility of MR imaging-guided percutaneous drainage of pancreatic fluid collections. J Vasc Interv Radiol. 2006;17(8):1321–6.
72. van Grinsven J, Timmerman P, Van Lienden KP, Dutch Pancreatitis Study Group. Proactive versus standard percutaneous catheter drainage for infected necrotizing pancreatitis. Pancreas. 2017;46(4):518–23.
73. Makris GC, See T, Winterbottom A, Jah A, Shaida N. Minimally invasive pancreatic necrosectomy; a technical pictorial review. Br J Radiol. 2018;91(1082):20170435.
74. Horvath K, Freeny P, Escallon J, et al. Safety and efficacy of video-assisted retroperitoneal debridement for infected pancreatic collections: a multicenter, prospective, single-arm phase 2 study. Arch Surg. 2010;145(9):817–25.
75. Nuñez D Jr, Yrizarry JM, Russell E, et al. Transgastric drainage of pancreatic fluid collections. AJR Am J Roentgenol. 1985;145(4):815–8.
76. Yamakado K, Takaki H, Nakatsuka A, et al. Percutaneous transhepatic drainage of inaccessible abdominal abscesses following abdominal surgery under real-time CT-fluoroscopic guidance. Cardiovasc Intervent Radiol. 2010;33(1):161–3.
77. Ciftci TT, Akinci D, Akhan O. Percutaneous transhepatic drainage of inaccessible post-operative abdominal abscesses. Am J Radiol. 2012;198:477–81.
78. Mueller PR, Ferrucci JT Jr, Simeone JF, et al. Lesser sac abscesses and fluid collections: drainage by transhepatic approach. Radiology. 1985;155(3):615–8.
79. Bassi C, Marchegiani G, Dervenis C, International Study Group on Pancreatic Surgery (ISGPS), et al. The 2016 update of the International Study Group (ISGPS) definition and grading of post-operative pancreatic fistula: 11 years after. Surgery. 2017;161(3):584–91.
80. Mallick B, Malik S, Gupta P, Gorsi U, Kochhar S, Gupta V, et al. Arterial pseudoaneurysms in acute and chronic pancreatitis: clinical profile and outcome. JGH Open. 2018;3(2):126–32.
81. Bansal A, Gupta P, Singh H. Gastrointestinal complications in acute and chronic pancreatitis. JGH Open. 2019;3(6):450–5. https://doi.org/10.1002/jgh3.12185.
82. Gupta P, Das GC, Samanta J, et al. Role of computed tomography in prediction of gastrointestinal fistula in patients with acute pancreatitis. Acta Gastroenterol Belg. 2019;82(4):495–500.
83. Hollemans RA, Bollen TL, van Brunschot S, Dutch Pancreatitis Study Group, et al. Predicting success of catheter drainage in infected necrotizing pancreatitis. Ann Surg. 2016;263(4):787–92.
84. Guo Q, Li A, Hu W. Predictive factors for successful ultrasound-guided percutaneous drainage in necrotizing pancreatitis. Surg Endosc. 2016;30:2929–34.
85. Li A, Cao F, Li J, Fang Y, Wang X, Liu DG, Li F. Step-up mini-invasive surgery for infected pancreatic necrosis: results from prospective cohort study. Pancreatology. 2016;16(4):508–14.
86. Babu RY, Gupta R, Kang M, Bhasin DK, Rana SS, Singh R. Predictors of surgery in patients with severe acute pancreatitis managed by the step-up approach. Ann Surg. 2013;257(4):737–50.
87. Walser EM, Nealon WH, Marroquin S, Raza S, Hernandez JA, Vasek J. Sterile fluid collections in acute pancreatitis: catheter drainage versus simple aspiration. Cardiovasc Intervent Radiol. 2006;29(1):102–7.
88. Gupta P, Gupta J, Kumar C, et al. Aggressive Percutaneous Catheter Drainage Protocol for Necrotic Pancreatic Collections [published online ahead of print, 2020 Feb 5]. Dig Dis Sci. 2020. https://doi.org/10.1007/s10620-020-06116-6.
89. Gupta P, Koshi S, Samanta J, Mandavdhare H, Sharma V, Sinha SK, Dutta U and Kochhar R: Kissing catheter technique for percutaneous catheter drainage of necrotic pancreatic collections in acute pancreatitis. Exp Ther Med. 2020;20:2311–6.

5 Interventions in Pancreatitis: Management of Vascular Complications

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5.1 Introduction

The incidence of major vascular involvement in pancreatitis is 1.2–14 % with a higher frequency of involvement in chronic pancreatitis (7–10%) compared to acute pancreatitis (1–6%). Mortality in patients with bleeding from major vascular involvement has been reported to be between 34% to 52% [1]. Bleeding in pancreatitis is usually due to the direct involvement of a vessel (mostly causing pseudoaneurysm formation) resulting in rupture into gastrointestinal tract/pseudocyst/abscess cavity/pancreatic duct/peritoneal cavity/retroperitoneum. Bleeding can also occur from varices due to the portal or splenic or mesenteric vein thrombosis. Other causes of bleeding include peptic ulcer disease (more prevalent in pancreatitis patients than the general population), Mallory-Weiss tears, splenic infarction, and splenic rupture [1, 2].

The risk factors described for vascular complications are necrotizing type of pancreatitis, organ failure involving multiple organs, sepsis, and pancreatic or peripancreatic fluid collections, history of necrosectomy, vasculitis, and patients on anticoagulants [3]. In a study by Bergert et al., major bleeding was due to pseudoaneurysm in 69.4% cases, peptic ulcers or varices in 22.2%, and splenic infarction or rupture in 8.4% cases [2].

5.2 Pathophysiology

Several pathogenic mechanisms are involved in the development of vascular complications. One is due to the adjacent extension of the inflammatory process, ischemic necrosis, and exocrine enzymes of the pancreas. If abscesses develop weeks to months later during the course of pancreatitis, associated infective organism also contributes to the vascular injury.

Pseudocysts can result in vascular injury due to compression, and elastolytic enzymes from their walls. Venous involvement is also due to the similar pathogenic mechanisms resulting in sinistral portal hypertension. Iatrogenic causes include surgery (necrosectomy) and percutaneous drain insertion due to direct vascular injury or mechanical irritation [1, 4]. Boudghene et al. reported the source of arterial bleeding as splenic artery in 42.4% cases, gastroduodenal artery (GDA) in 21.7%, pancreaticoduodenal arteries in 25.5%, hepatic artery and superior mesenteric artery (SMA) in 2.8% each, jejunal arteries in 1.9%, other intestinal arteries and renal arteries in 0.9% each [5].

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5.3 Vascular Anatomy and Anastomotic Pathways

The various branches of celiac and superior mesenteric arteries supplying the pancreas are depicted in Fig. 5.1. Various anastomotic pathways described are between superior and inferior pancreaticoduodenal arteries, between DPA and SPDAs, between DPA, TPA, and GPA, between caudal pancreatic arteries and TPA, GPA. Arc of Buhler is the persistent embryonic connection between the celiac artery and SMA independent of GDA and DPA. Arc of Barkow is formed by communication between the right and left gastroepiploic arteries [6–8]. Knowledge of these anastomoses is important for effective endovascular treatment and to prevent recanalization of the pseudoaneurysm.

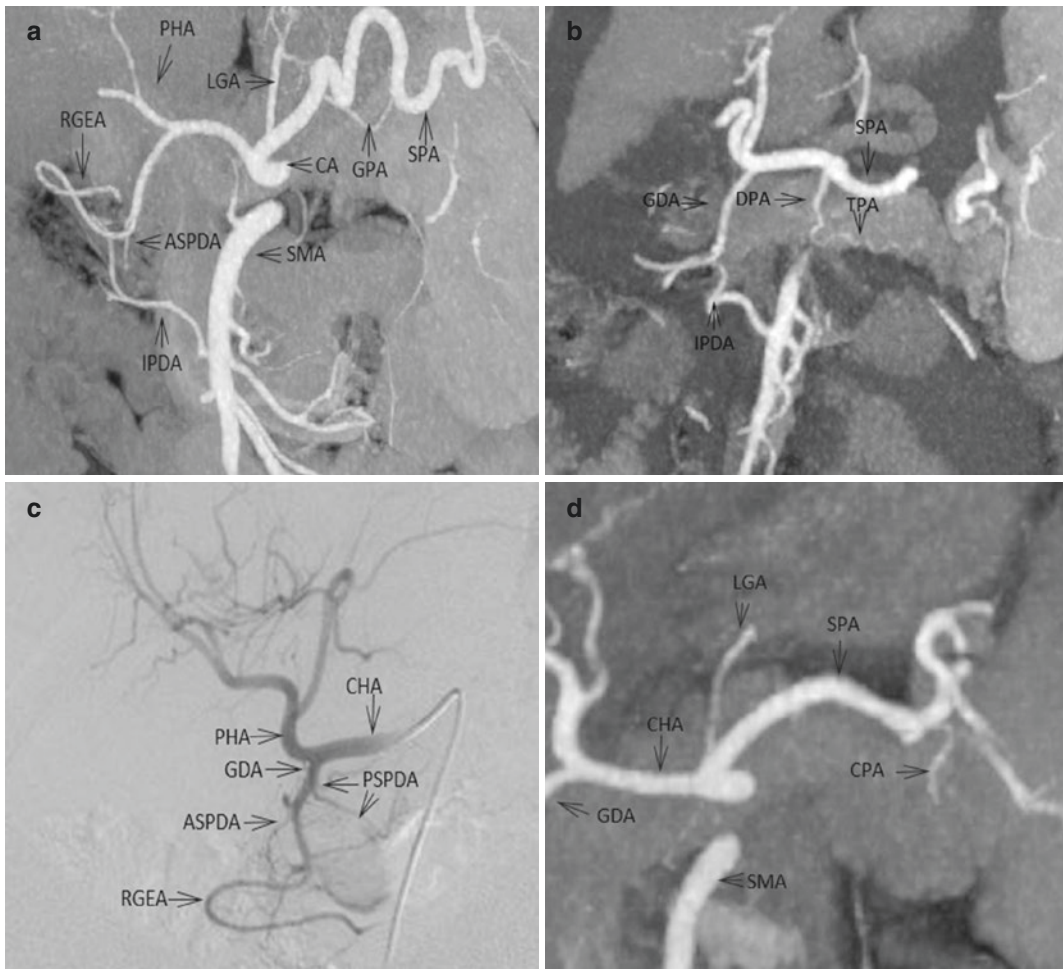


Fig. 5.1 Arterial supply to the pancreas: Maximum Intensity Projections of CT Angiography in coronal oblique plane (**a**, **b** and **d**) and selective digital subtraction angiogram of common hepatic artery (**c**) showing arterial supply to pancreas. Anterior superior pancreaticoduodenal artery (ASPDA), Caudal pancreatic arteries (CPA), Celiac artery (CA), Common hepatic artery (CHA), Dorsal pancreatic artery (DPA), Gastroduodenal artery (GDA), Great pancreatic artery (GPA), Inferior pancreaticoduodenal artery (IPDA), Left gastric artery (LGA), Posterior superior pancreaticoduodenal artery (PSPDA), Proper hepatic artery (PHA), Right gastroepiploic artery (RGEA), Splenic artery (SPA), Superior mesenteric artery (SMA), Transverse pancreatic artery (TPA)

5.4 Clinical Features

Bleeding in pancreatitis can be gastrointestinal (GI) bleed or non-gastrointestinal bleed. GI bleed presents as hematemesis, melena, or rarely haematochezia. Non-GI bleed presents as abdominal pain or hemorrhagic shock. Most of these patients have a drop in hemoglobin of at least 2–3 gm/dl. Some of the pseudoaneurysms may be incidentally detected on imaging [3]. The role of imaging modalities is described in Table 5.1.

5.5 Treatment Approach to Vascular Complications of Pancreatitis

Most authors advise treatment of all the pseudoaneurysms detected at the earliest as the mortality rates of their rupture can be up to 100%. There are no guidelines for the timing of treatment in pseudoaneurysms. However, regarding the choice of treatment, the International Association of Pancreatology/American Pancreatic Association guidelines for acute pancreatitis and United European Gastroenterology guidelines for chronic pancreatitis recommend endovascular treatment as the initial choice of treatment for pseudoaneurysms [9, 10].

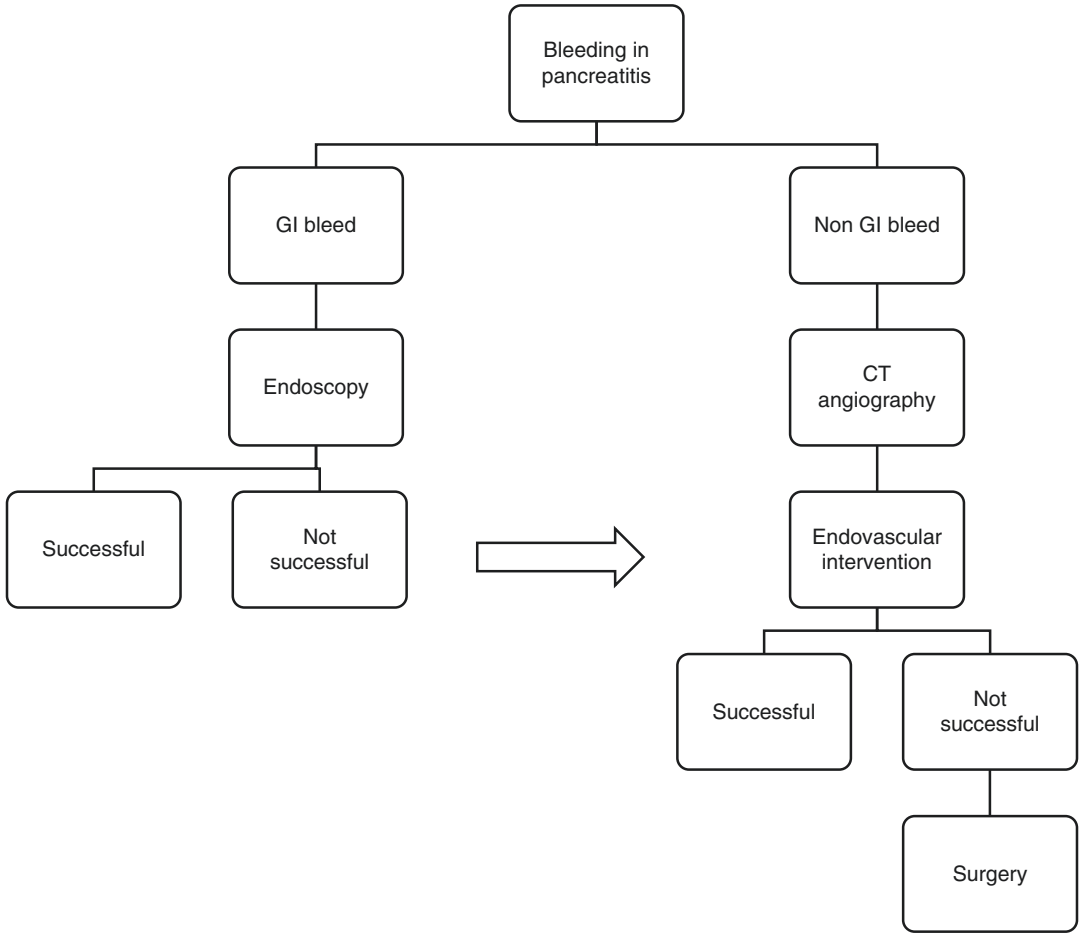
Bergert et al and Balachandra et al reported higher mortality rates in surgery first approach compared to endovascular first approach [2, 11]. Hemorrhagic shock and the number of units of blood transfused (>10) were found to be significant predictors of mortality. The endovascular approach required fewer units of blood and shorter hospital stay [2, 12]. The algorithm proposed by various authors for the management of bleeding in pancreatitis is given in Flowchart 5.1 [2, 3, 13]. Hardware required for endovascular intervention is described in Table 5.2.

5.6 Endovascular Therapy of Pseudoaneurysms/ Arterial Bleeding in Pancreatitis

Standard pre-procedural preparation and contraindications for catheter-directed angiography are also applied here [14]. The femoral arterial access is the preferred route with brachial or axillary approach reserved for those with acute-angled origins of feeders from the aorta. Angled catheters like MPA are used for cannulating the arteries arising from the aorta with an angle of origin between 0 to 60 degrees and curved catheters like Cobra 2 are used if the angle is

Table 5.1 Role of different imaging modalities in vascular complications of pancreatitis

Ultrasound	CT angiography	DSA angiography
Advantages • Can be done on bedside • Easily available • Cheaper • No radiation exposure • Contrast enhanced ultrasound can be useful in patients where iodinated contrast cannot be used *Disadvantages* • Operator dependant • Meteorism and obesity can obscure visibility	Most commonly used investigation for diagnosis *Advantages* • Not operator dependant • Fast • Highly accurate • Shows extraluminal features of pseudoaneurysm • MIP, 3D, and VR reformats helpful before intervention for planning *Disadvantages* • Radiation exposure • Contrast cannot be used in allergic or renal compromise patients	Gold standard investigation *Advantages* • Real-time evaluation of collateral supply to assess the expendability of artery • Treatment can also be done during angiography • Most sensitive to detect active bleeding and small pseudoaneurysms *Disadvantages* • Apart from sharing the disadvantages of CT angiography, there are other risks of this invasive modality discussed in complications section of this chapter



Flowchart 5.1 Approach to management of bleeding in pancreatitis

Table 5.2 Hardware required for endovascular management of vascular complications in pancreatitis

1. 18G puncture needle
2. Micropuncture set 4F
3. Arterial sheath (5F or 6F, 11 cm for initial access and other sizes and lengths depending on the stent size and vessel). E.g., Super ArrowFlex® (Teleflex): 5F–11F, 11–90 cm, Destination® (Terumo): 5F–8F, 45–90 cm, Performer™ Guiding sheath (Cook Medical): 5F–16F, 48–85 cm.
4. Hydrophilic guidewire. E.g., Glidewire® (Terumo): 0.035″–150 cm, 260 cm, angled tip
5. Stiff guidewire. E.g., Amplatz® (Cook Medical): 0.035″–150 cm, 260 cm
6. Diagnostic catheters. E.g., MPA, C2, SIM1, H1, Picard: 5F or 4F
7. Microcatheters. E.g., Progreat® coaxial (Terumo): 2.7F, 2.8F, Renegade™ (Boston Scientific)-2.4F-2.8F, Direxion™ (Boston Scientific): 2.4F, 2.8F.
8. Pushable coils-0018″ and 0.035″. E.g., MReye® (Cook Medical), Nester® (Cook Medical), VortX® (Boston Scientific)
9. Detachable coils. E.g., GDC® (Stryker), Target® (Stryker), Hydrocoil® (MicroVention)
10. Covered stent grafts. E.g., Fluency® Plus (BD Interventional): 6–13.5 mm, Graft master® (Abbott): 2.8–4.8 mm diameter.
11. Thrombin
12. Glue
13. Heparin
14. Nitroglycerin (used in case of vasospasm)

between 60 to 120 degrees and reverse curve catheters like Simmons 1 are used if the angle is greater than 120 degrees [15].

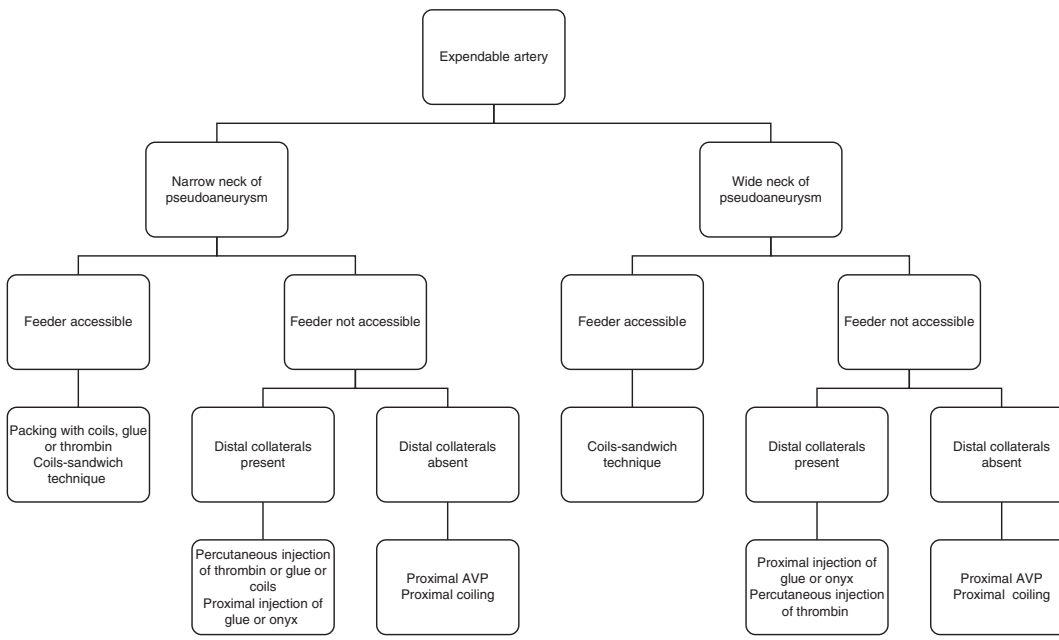
After diagnostic angiograms, the smaller feeding arteries can be selectively catheterized using microcatheters. Cannulating the left gastric artery can be difficult. Various techniques described are: forming Waltman loop, using a reverse curved catheter, side hole creation in the shepherd's hook catheter, and passing microcatheter through this side hole [16].

The choice of endovascular treatment depends on the expendability of the artery, tortuosity/angle of origin of the arteries. The expendable arteries are the splenic, gastroduodenal, and inferior pancreaticoduodenal arteries. SMA, intestinal arteries, celiac artery trifurcation (pseudoaneurysm arising from trifurcation) are considered as nonexpendable arteries. There are case reports in which proper hepatic artery was embolized if there is sufficient collateral circulation from SMA with patent portal vein. The proposed selection of treatment by various authors is given in Flowcharts 5.2 and 5.3 [17–19].

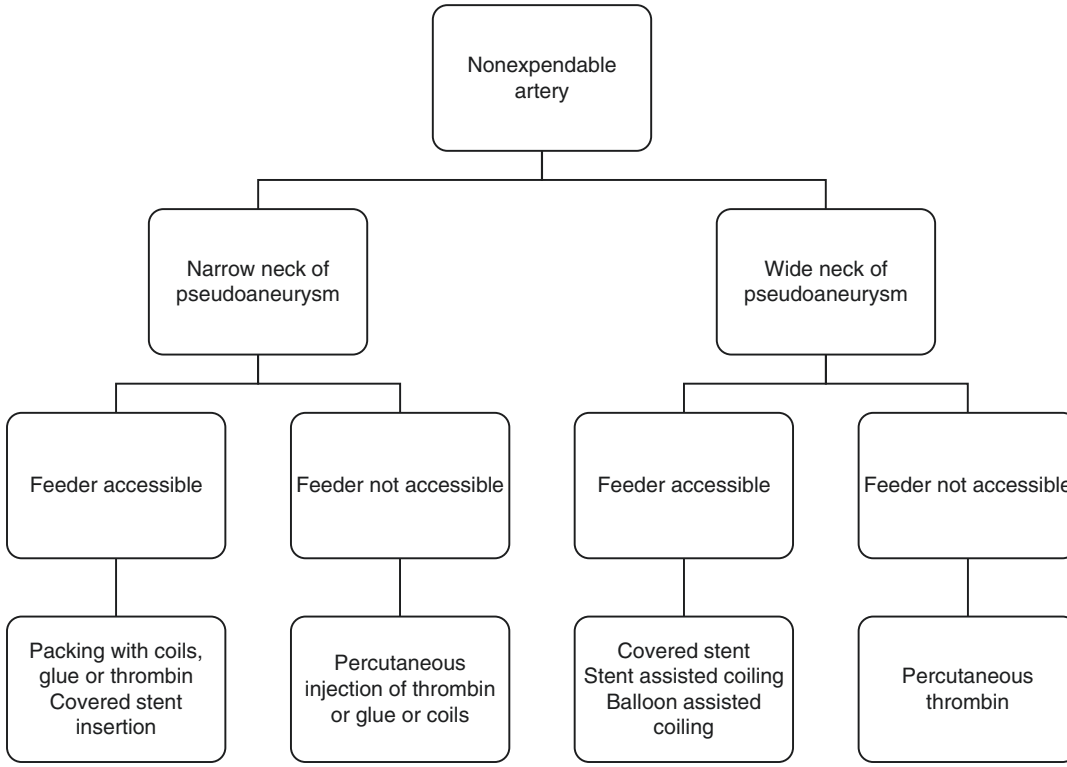
5.6.1 Embolization with Coils

This is the most commonly described technique for the endovascular management of pseudoaneurysms. If an expendable bleeding vessel could be selectively cannulated, then the coils can be placed on either side of the neck of pseudoaneurysm in distal to the proximal direction ("sandwich" technique). This is to prevent the revascularisation of the pseudoaneurysm by the collaterals (Figs. 5.2, 5.3, and 5.4). Twenty to thirty percent oversizing of coils is recommended relative to the vessel. In case of a nonexpendable bleeding vessel, if the pseudoaneurysm (with narrow neck) can be selectively cannulated, then detachable coils can be implanted directly. The detachable coils offer the advantage of precise placement and they can be withdrawn if not placed appropriately.

In case of a nonexpendable bleeding vessel with wide neck, coils cannot be directly placed into the pseudoaneurysm in this scenario, as there is a risk of coil migration into the parent artery (up to 3%). If the covered stent could not be



Flowchart 5.2 Approach to endovascular treatment in expendable artery



Flowchart 5.3 Approach to endovascular treatment in nonexpendable artery

placed due to tortuous anatomy or nonavailability, then stent-assisted coiling can be done. In this technique, an uncovered stent is placed across the pseudoaneurysm neck followed by the insertion of coils into the pseudoaneurysm through the interstices of the stent. Another technique is the "balloon-assisted remodeling" in which a balloon is inflated across the neck and a catheter is passed adjacent to inflated balloon into the pseudoaneurysm sac for coil packing [1, 19].

However, there are situations in which nonexpendable artery needs to be embolized proximally if the patient is hemodynamically unstable, unfit for surgery and the pseudoaneurysm cannot be accessed by endovascular or percutaneous or endoscopic ultrasound (EUS) route [1]. In patients with coagulopathy or shock adjuvant use of gelfoam or thrombin is needed for occlusion of the vessel [1, 20]. Technical success of 67% to 100% has been described in literature, rebleed in 5.7% to 17%, and complications in 0% to 17% [12, 21, 22]. Udd et al. reported decreased technical success for the embolization of splenic artery bleeders due to pseudocysts located in the body and tail of the pancreas [12].

5.6.2 Liquid Embolic Agents

Thrombin (bovine or human), an adhesive liquid embolic agent can be used by the endovascular route in a nonexpendable artery where covered stent insertion is not feasible or not affordable. This is also used for occlusion of pseudoaneurysms arising from the expendable artery if coil insertion is not feasible [18]. USG or CT guided percutaneous injection using 22G needle is also a described technique, if the neck is not accessible by the endovascular route. Some authors routinely use this technique for all the pseudoaneurysms [23]. The amount of thrombin injected depends upon the pseudoaneurysm cavity size and flow rate. Most authors used 1000 to 1500 IU during percutaneous injection [24]. Zabicki et al

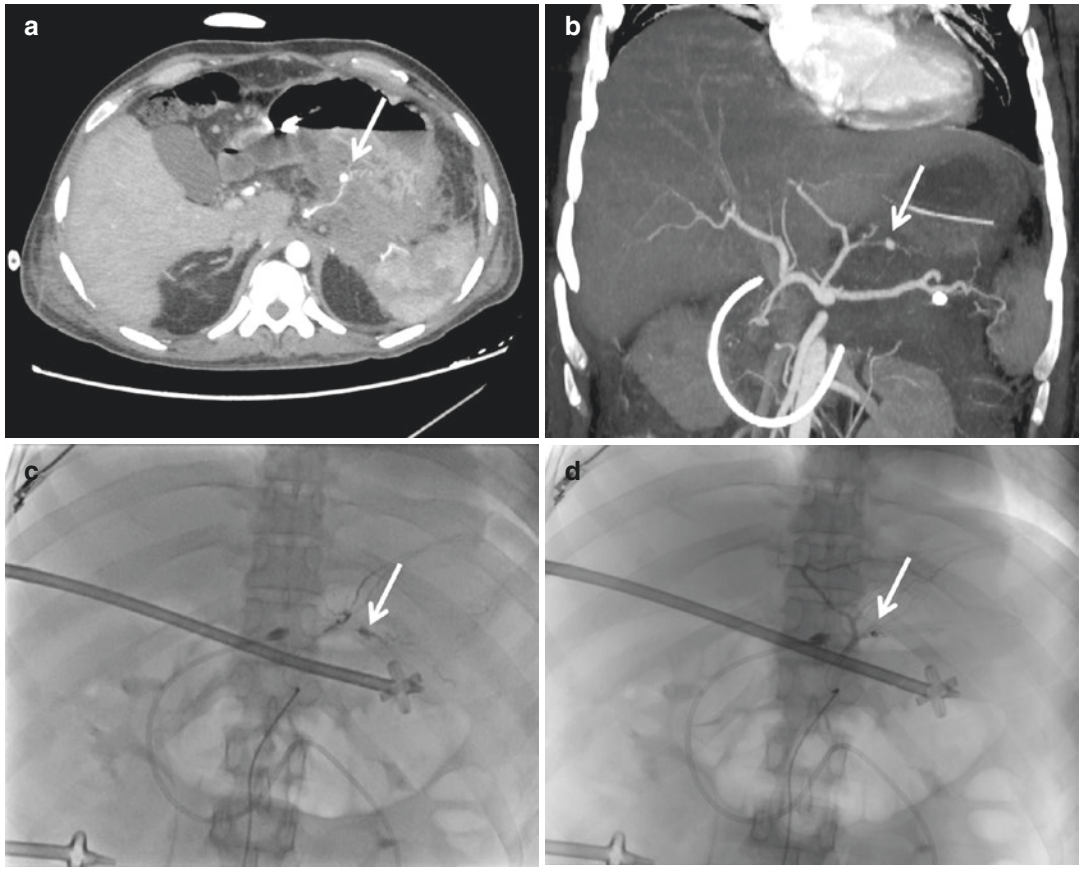


Fig. 5.2 38 years old male with acute pancreatitis and hemoglobin drop. (**a**) Axial CECT image showing pseudoaneurysm arising from the left gastric artery. (**b**) Oblique coronal MIP image shows pseudoaneurysm arising from the left gastric artery. (**c**) Selective angiogram showing pseudoaneurysm from the left gastric artery. (**d**) Coiling (arrow) of pseudoaneurysm was done and check angiogram shows no flow in the pseudoaneurysm

initiated endovascular injection with 400 IU for cavity diameter less than 2 cm and 800 IU for >2 cm cavities and adjusted the dose depending on the residual flow in the pseudoaneurysm [18].

Thrombin is not effective in pseudoaneurysms with high flow rate and in coagulopathic patients. In these situations, adjuvant insertion of coils is proposed by authors if the pseudoaneurysm neck is narrow. This adjuvant use of other embolizing agents is also recommended in critical situations where immediate occlusion is needed. Complications reported with the use of thrombin include parent artery occlusion, AV fistulas. Allergic reactions can be minimized with the use of human thrombin [18]. Among the case reports on visceral artery pseudoaneurysm embolization with thrombin, 100% technical success rate was reported, with adjuvant use of coils in only 5.3%. The rebleed rates were reported in up to 21% cases, so close surveillance for revascularisation is recommended [24].

Other liquid embolic agents like *onyx and glue (n Butyl Cyanoacrylate)* are injected when the bleeding vessel cannot be accessed. These are mostly used for expendable arteries [18]. However, some authors used glue injection for selective embolization of pseudoaneurysm in nonexpendable arteries [25]. These agents have the advantage of occluding all the downstream smaller branches, collaterals from the point of injection, and also the potential for occlusion in coagulopathic patients. The disadvantages include adherence of the embolising agent to catheter and embolization of non-target vessels in

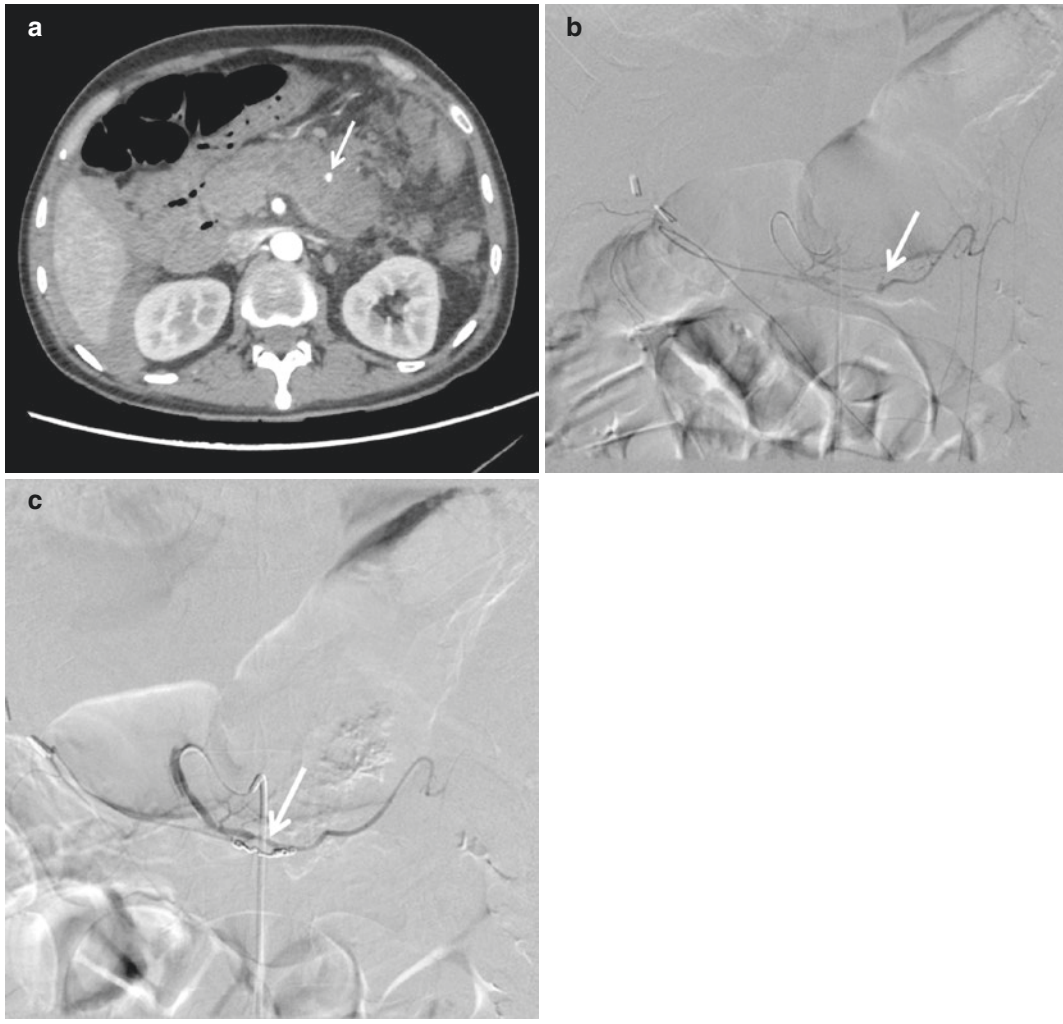


Fig. 5.3 30 years old male with acute pancreatitis and hemorrhagic shock. (**a**) Axial CECT shows arterial blush within the acute necrotising collection in the peripancreatic region. (**b**) Selective angiogram showing pseudoaneurysm from the right gastroepiploic artery. (**c**) Coiling of pseudoaneurysm was done and check angiogram shows no flow within the pseudoaneurysm

the hands of inexperienced interventionists [18]. Loffroy et al. advised against the use of glue in pseudoaneurysms arising from the proximal aspect of large nonexpendable arteries [26].

Lipiodol is mixed with glue to adjust the rate of polymerization. The amount of mixture injected at a time depends on the microcatheter dead space (usually 0.1–0.3 ml), size of parent artery, size of the pseudoaneurysm, and flow dynamics. Slower injection to prevent reflux, test injection with contrast, immediate withdrawal of microcatheter and residual glue aspiration through guiding catheter are recommended techniques to prevent complications. Madhusudhan et al proposed a "sequential injection flushing technique" to improve the safety of glue embolization. Microcatheter was flushed with 5% dextrose after glue injection. Recent studies on glue embolization reported technical success of 94% to 100%, rebleed in 0% to 15% and major complications in 0% to 25% [25, 27].

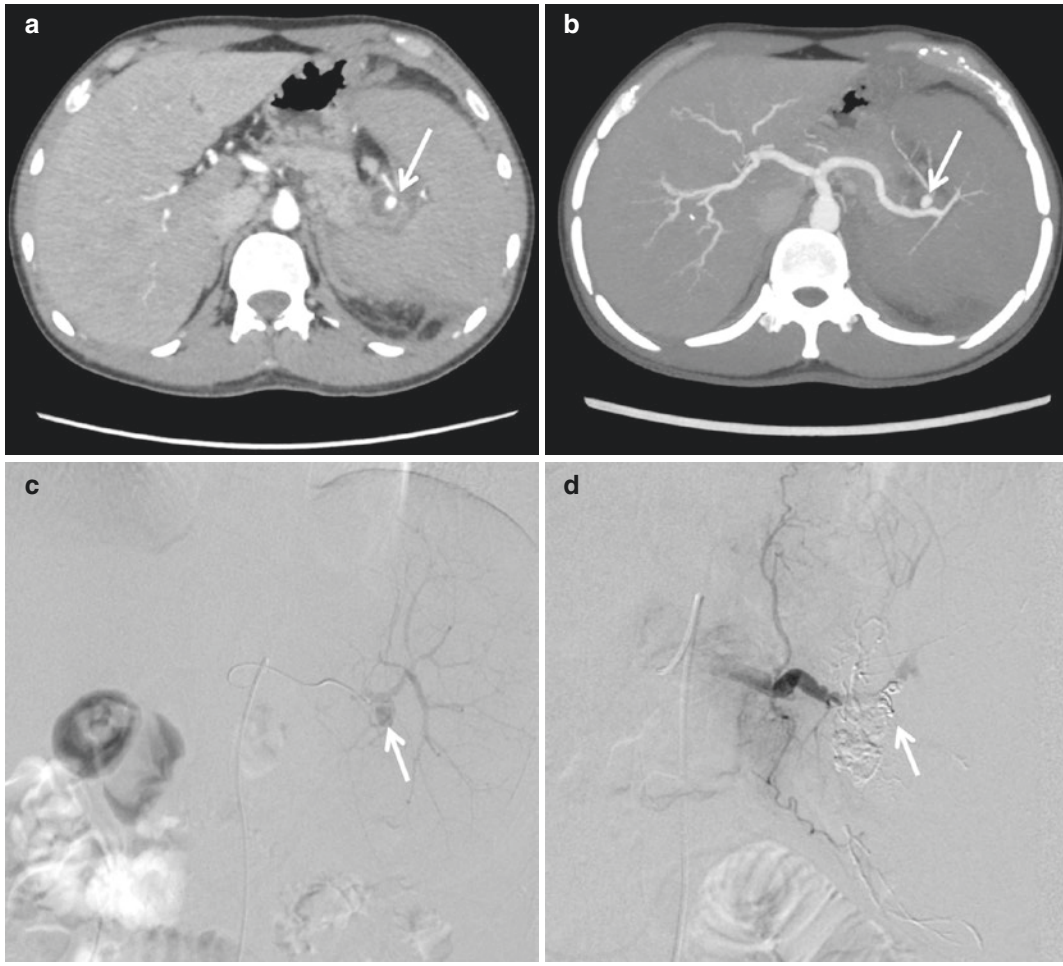


Fig. 5.4 Forty two years old female with chronic pancreatitis and asymptomatic. (**a**) Axial CECT shows small focal collection adjacent to tail of pancreas with arterial blush within. (**b**) Oblique axial MIP image shows pseudoaneurysm arising from splenic artery. (**c**) Selective angiogram showing pseudoaneurysm from splenic artery. (**d**) Coiling of pseudoaneurysm was done and check angiogram shows no flow within the pseudoaneurysm

5.6.3 Stents

Covered stent insertion is a commonly described technique for the treatment of pseudoaneurysms arising from a nonexpendable artery. These are mostly preferred in arteries with a straight course and a caliber ≥ 6 mm (e.g. SMA) [18]. However recent studies reported usage of flexible covered stents in tortuous visceral arteries (common hepatic artery, celiac trunk, gastroduodenal artery, splenic artery, and renal artery) with the technical success of 84.2% to 100% [28, 29]. Stent thrombosis is a potential complication particularly in those with smaller vessels, smokers, chronic diseases like diabetes mellitus. Occlusion of the branches arising from the parent artery is also a potential complication [18].

Flow diverter stents are the self-expandable, uncovered stents with multiple layers which modulate the flow leading to a decrease in the velocity and turbulence in the aneurysm/pseudoaneurysm leading to gradual thrombosis. If there is a side branch arising from the aneurysm/pseudoaneurysm, the flow will be preferentially directed to that side branch due to Venturi effect thereby preventing its occlusion.

These stents are used in many extra cranial nonexpendable arteries like hepatic artery, celiac

trunk, SMA [19]. Ruffino et al reported a technical success rate of 100% and stent thrombosis of 11.1% at the end of 1 year [30]. Antiplatelet therapy is routinely prescribed after covered or flow diverter stent insertion. Clopidogrel (75 mg/day) for 4–6 weeks and lifelong aspirin (75–100 mg/day) are the drugs which are commonly prescribed [24, 28].

5.6.4 Amplatzer Vascular Plugs

Amplatzer vascular plugs are well suited for large caliber expendable vessels which do not have collaterals distally leading to revascularisation of the pseudoaneurysm. They have the advantages of faster, reliable embolization, accurate positioning, short landing zone, ability to retrieve and reposition if malpositioned. The requirement issues of larger sheaths and a straighter vessel are solved by the new generation AVPs. All manufacturers advise 30–50% oversizing of the AVP compared to the vessel [18]. In one study, there was technical success of 96% for gastroduodenal artery occlusion with AVP II and only one patient (4%) required additional coils placement [31]. However, Zhu et al. reported the use of additional embolization agents in 78% patients for occlusion of the proximal splenic artery [32].

5.7 Venous Complications in Pancreatitis

The role of interventional radiology is in two scenarios. One is in patients with bleeding from sinistral portal hypertension. If the patients are not fit for surgery (splenectomy), then partial splenic artery embolization can be performed in this scenario. Also, preoperative embolization can be done if the patient is fit for surgery to minimize bleeding during splenectomy. The other scenario is in the cavernous transformation of the portal vein with bleeding. If the bleeding is not controlled by endoscopy, TIPS can be performed if feasible [33].

5.8 Complications

Apart from puncture-related complications, the embolization procedure-related complications include pseudoaneurysm rupture, arterial dissection, and non-target embolization leading to organ ischemia. Pseudoaneurysm rupture during endovascular embolization is dealt with liquid embolic agents or gelfoam embolization. Rupture during percutaneous embolization requires emergent endovascular or surgical management. Flow limiting arterial dissection of a large proximal vessel is treated by heparin injection and balloon angioplasty/stent insertion. Splenectomy or bowel resection may be needed in patients with severe persistent symptoms due to organ ischemia. Complications after embolization include post embolization syndrome which is managed by symptomatic treatment and abscess formation in target organ which requires percutaneous drainage. Post-procedure vitals and hemoglobin monitoring are recommended for early detection of rebleed [1, 19].

5.9 Conclusion

Vascular complications are one of the significant causes of mortality in patients with pancreatitis. Careful evaluation, early detection, and multidisciplinary treatment approach can significantly reduce the mortality. Most of the guidelines recommend endovascular treatment as initial choice of treatment for non-gastrointestinal bleed. Assessing the bleeding vessel, pseudoaneurysm, collaterals, affordability, local availability of expertise, and hardware determine the choice of the endovascular technique.

References

1. Barge JU, Lopera JE. Vascular complications of pancreatitis: role of interventional therapy. Korean J Radiol. 2012;13(Suppl 1):S45–55.
2. Bergert H, Hinterseher I, Kersting S, Leonhardt J, Bloomenthal A, Saeger HD. Management and outcome of hemorrhage due to arterial pseudoaneurysms in pancreatitis. Surgery. 2005;137(3):323–8.

3. Sharma PK, Madan K, Garg PK. Hemorrhage in acute pancreatitis: should gastrointestinal bleeding be considered an organ failure? Pancreas. 2008;36(2):141–5.
4. Flati G, Andren-Sandberg A, La Pinta M, Porowska B, Carboni M. Potentially fatal bleeding in acute pancreatitis: pathophysiology, prevention, and treatment. Pancreas. 2003;26(1):8–14.
5. Boudghene F, L'Hermine C, Bigot JM. Arterial complications of pancreatitis: diagnostic and therapeutic aspects in 104 cases. J Vasc Interv Radiol. 1993;4(4):551–8.
6. Kaufman JA, Lee MJ. Vascular and interventional radiology: the requisites. London: Elsevier Health Sciences; 2013.
7. Okahara M, Mori H, Kiyosue H, Yamada Y, Sagara Y, Matsumoto S. Arterial supply to the pancreas; variations and cross-sectional anatomy. Abdom Imaging. 2010;35(2):134–42.
8. Uflacker R, Selby B, Ovid Technologies I. Atlas of vascular anatomy: an angiographic approach. Philadelphia: Lippincott Williams & Wilkins; 2007.
9. Working Group IAPAPAAPG. IAP/APA evidence-based guidelines for the management of acute pancreatitis. Pancreatology. 2013;13(4 Suppl 2):e1–15.
10. Lohr JM, Dominguez-Munoz E, Rosendahl J, Besselink M, Mayerle J, Lerch MM, et al. United European Gastroenterology evidence-based guidelines for the diagnosis and therapy of chronic pancreatitis (HaPanEU). United European Gastroenterol J. 2017;5(2):153–99.
11. Balachandra S, Siriwardena AK. Systematic appraisal of the management of the major vascular complications of pancreatitis. Am J Surg. 2005;190(3):489–95.
12. Udd M, Leppaniemi AK, Bidel S, Keto P, Roth WD, Haapiainen RK. Treatment of bleeding pseudoaneurysms in patients with chronic pancreatitis. World J Surg. 2007;31(3):504–10.
13. Nicholson AA, Patel J, McPherson S, Shaw DR, Kessel D. Endovascular treatment of visceral aneurysms associated with pancreatitis and a suggested classification with therapeutic implications. J Vasc Interv Radiol. 2006;17(8):1279–85.
14. Kandarpa K, Machan L, Durham JD. Handbook of interventional radiologic procedures. New York: Wolters Kluwer; 2016.
15. Mauro MA, Murphy K, Thomson KR, Venbrux AC, Morgan RA. Image-guided interventions. Philadelphia, PA: Elsevier; 2014.
16. Miyazaki M, Shibuya K, Tsushima Y, Endo K. Catheterization and embolization of a replaced left hepatic artery via the right gastric artery through the anastomosis: a case report. J Med Case Reports. 2011;5:346.
17. Saad NE, Saad WE, Davies MG, Waldman DL, Fultz PJ, Rubens DJ. Pseudoaneurysms and the role of minimally invasive techniques in their management. Radiographics. 2005;25(Suppl 1):S173–89.
18. Zabicki B, Limphaibool N, Holstad MJV, Juszkat R. Endovascular management of pancreatitis-related pseudoaneurysms: a review of techniques. PLoS One. 2018;13(1):e0191998.
19. Madhusudhan KS, Venkatesh HA, Gamanagatti S, Garg P, Srivastava DN. Interventional radiology in the management of visceral artery pseudoaneurysms: a review of techniques and embolic materials. Korean J Radiol. 2016;17(3):351–63.
20. Loffroy R, Rao P, Ota S, De Lin M, Kwak BK, Krause D, et al. Packing technique for endovascular coil embolisation of peripheral arterial pseudoaneurysms with preservation of the parent artery: safety, efficacy and outcomes. Eur J Vasc Endovasc Surg. 2010;40(2):209–15.
21. Ikeda O, Nakasone Y, Tamura Y, Yamashita Y. Endovascular management of visceral artery pseudoaneurysms: transcatheter coil embolization using the isolation technique. Cardiovasc Intervent Radiol. 2010;33(6):1128–34.
22. Dohan A, Eveno C, Dautry R, Guerrache Y, Camus M, Boudiaf M, et al. Role and effectiveness of percutaneous arterial embolization in hemodynamically unstable patients with ruptured splanchnic artery pseudoaneurysms. Cardiovasc Intervent Radiol. 2015;38(4):862–70.
23. Ward EV, Buckley O, Doody O, Govender P, Conlon K, Torreggiani WC. Percutaneous thrombin embolization of a ruptured peripancreatic pseudoaneurysm. Digestion. 2007;76(3-4):188–91.
24. Barbiero G, Battistel M, Susac A, Miotto D. Percutaneous thrombin embolization of a pancreatico-duodenal artery pseudoaneurysm after failing of the endovascular treatment. World J Radiol. 2014;6(8):629–35.
25. Madhusudhan KS, Gamanagatti S, Garg P, Shalimar DNR, Pal S, et al. Endovascular embolization of visceral artery pseudoaneurysms using modified injection technique with N-butyl cyanoacrylate glue. J Vasc Interv Radiol. 2015;26(11):1718–25.
26. Loffroy R. Re: Transcatheter N-butyl cyanoacrylate embolization of pseudoaneurysms. J Vasc Interv Radiol. 2011;22(3):414–5.
27. Shakur SF, Brunozzi D, Alaraj A. Glue embolization with guide catheter dextrose push of recurrent dural arteriovenous fistula previously embolized with onyx: neuroendovascular surgical video. World Neurosurg. 2019;126:466.
28. Anton S, Stahlberg E, Horn M, Wiedner M, Kleemann M, Barkhausen J, et al. Initial experience with the E-ventus(R) stent-graft for endovascular treatment of visceral artery aneurysms. J Cardiovasc Surg (Torino). 2018;59(2):225–31.
29. Kunzle S, Glenck M, Puippe G, Schadde E, Mayer D, Pfammatter T. Stent-graft repairs of visceral and renal artery aneurysms are effective and result in long-term patency. J Vasc Interv Radiol. 2013;24(7):989–96.
30. Ruffino M, Rabbia C, Italian Cardiatis Registry Investiagtors Group. Endovascular treatment of visceral artery aneurysms with Cardiatis multilayer flow modulator: preliminary results at six-month follow-up. J Cardiovasc Surg (Torino). 2011;52:311–21.

31. Pech M, Kraetsch A, Wieners G, Redlich U, Gaffke G, Ricke J, et al. Embolization of the gastroduodenal artery before selective internal radiotherapy: a prospectively randomized trial comparing platinum-fibered microcoils with the Amplatzer Vascular Plug II. Cardiovasc Intervent Radiol. 2009;32(3):455–61.
32. Zhu X, Tam MD, Pierce G, McLennan G, Sands MJ, Lieber MS, et al. Utility of the amplatzer vascular plug in splenic artery embolization: a comparison study with conventional coil technique. Cardiovasc Intervent Radiol. 2011;34(3):522–31.
33. Aswani Y, Hira P. Venous complications of pancreatitis: a review. JOP. 2015 Jan 31;16(1):20–4.

6 IR Management of Liver and Splenic Trauma

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6.1 Liver Injury

Interventional radiology, in many ways, has transformed the management of patients with liver trauma who present to the hospital with hemodynamic instability or features of active bleeding. The indication for embolization in liver trauma can be summarized from the consensus statement of the world society of emergency surgery wherein any patient with hemodynamic instability or with major liver injury could be considered for embolization [1]. Several papers have been published where the emphasis has been on CT when the patient is hemodynamically stable and surgery or angiography with embolization without CT in a hemodynamically unstable patient [2–4]. However, it has been our experience that if a patient can be stabilized to some extent with the help of anesthetists or intensivists, a CT should be attempted whenever possible, since it helps plan the procedure better and further enables us to complete the procedure quickly and efficiently.

Current indications for embolization are [1, 5–7]:

1. Hemodynamically unstable patients
2. Active extravasation of contrast during CT
3. Vascular blush on CT

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6.2 CT in Abdominal Trauma

Trauma is very rarely limited to a single organ structure. CT is the most accurate way to look for injuries to the solid and hollow organs and further pickup active bleeding when present. Further, modern multi-slice CTs allow excellent visualization of the arterial anatomy which is crucial in planning appropriate hardware necessary to perform successful embolization, especially, in patients who are otherwise sick, where time is crucial in the final outcome.

CT should ideally be done in a multi-slice system with a minimum of 16 rows of detectors in both the arterial and the venous phase. A delayed phase is useful in small vessel bleeds where puddling of contrast is better appreciated with time. The liver receives supply predominantly from the portal vein, however, hemodynamic instability is usually associated with extravasation from the hepatic artery. The main hepatic artery arises from the celiac trunk and usually divides into the left and right hepatic arteries, however, it is important to keep in mind, that the origin of these arteries and the area supplied can be variable (Table 6.1) [8]

In elderly patients, the celiac axis can be elongated, tortuous, and angulated, making transfemoral access to the vessel difficult and prior planning based on the anatomy can enable

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Table 6.1 Hepatic arterial variations and their frequencies

Type	Frequency (%)	Description
I	55	RHA, MHA, and LHA arise from the CHA
II	10	RHA, MHA, and LHA arise from the CHA; replaced LHA from the LGA
III	11	RHA and MHA arise from the CHA; replaced RHA from the SMA
IV	1	Replaced RHA and LHA
V	8	RHA, MHA, and LHA arise from the CHA; accessory LHA from the LGA
VI	7	RHA, MHA, and LHA arise from the CHA; accessory RHA
VII	1	Accessory RHA and LHA
VIII	4	Replaced RHA and accessory LHA or replaced LHA and accessory RHA
IX	4.5	Entire hepatic trunk arises from the SMA
X	0.5	Entire hepatic trunk arises from the LGA

us to take a trans-radial access. CT also can demonstrate the actual vessel which is bleeding or supplying the injured region with much greater clarity due to its ability to be reformatted in any plane and further volume rendered 3D images can be used to study the vascular supply to the injured region in exquisite detail.

Things to look for in a CT scan

A. The culprit vessel can be identified by the presence of
   (a) Active bleeding
   (b) Vascular blush
   (c) Pseudoaneurysm/Arteriovenous (AV) or arterioportal fistula
B. Vascular anatomy
   (a) Look for origin of the vessel, especially, to see the angle at which it takes off from the aorta. Evaluate the vessel in its entire length, especially, looking for tortuosity, dissections, and difficult loops to ensure that your hardware is appropriately selected.
   (b) Look for the number of vessels supplying the liver, especially, since the right hepatic artery can often arise from the superior mesenteric artery at a difficult angle. Similarly, the left hepatic artery can arise from the left gastric artery.
   (c) Look for the portal vein. Embolisation of the hepatic artery in a patient with occluded portal vein can lead to ischemic necrosis of the liver.

6.2.1 Angiography in Hepatic Trauma

Equipment: The ideal equipment should be a cath lab with a 30 × 40 cm flat panel detector with DSA and facility to do 3D and cone beam CT. Although DSA is ideal, it can be extremely difficult in a patient who is not ventilated and is restless. In these cases taking advantage of the CT anatomy, the segmental artery can be accessed and then angiography of the selected region can give clarity regarding the vessel to be embolized. A ventilated paralyzed patient gives us the advantage of control over the respiration which in turn gives excellent DSA images and helps detect areas with abnormality with greater clarity. Typically, angiography is done at 4 or more frames/sec.

6.2.2 Access

Femoral access continues to be the commonest site. However, if the takeoff of the celiac axis, SMA or a hepatic artery arising directly from the aorta is at a steep angle, then cannulating these vessels and navigating a catheter distally can prove to be difficult and in these patients a trans-radial or trans-brachial approach can be taken.

If the patient is young and the vascular anatomy is not complicated with loops, then a diagnostic catheter like Yashiro (Terumo Corporation), Simmons 1, or Cobra can be used to cannulate the common hepatic artery over an angled 0.035″ guide

wire (Terumo). The target vessel is best catheterized by using a microcatheter using a 0.025″ (Progreat-Terumo, Headway 21-microvention, XT 27-stryker) lumen to allow embolization with 0.018″ microcoils, 500–700 microns PVA (polyvinyl alcohol particles), gelfoam scrapings, or n-Butyl cyanoacrylate (NBCA/glue).

However, if the vessel is tortuous or if the culprit vessel comes from a branch which may be difficult to cannulate, then using a 40 cm, 5 Fr Ansel sheath (cook) not only helps in support but also allows multiple injections during the procedure to enable localization of the bleeding vessel. So, a Simmons or Yashiro catheter is taken through the 5 Fr long sheath and the sheath is taken into the common hepatic artery over the diagnostic catheter-guide wire combination. Long sheath also gives stability to the diagnostic catheter which is helpful when coiling the target vessel.

6.2.3 Materials Used for Embolisation

When a proximal vessel needs to be sacrificed, then the best choice would be to place multiple coils across the rent in such a way that there are multiple coils both proximal and distal to the diseased segments (Figs. 6.1 and 6.2). However, when the bleeding vessel is distal one can use gelfoam, PVA

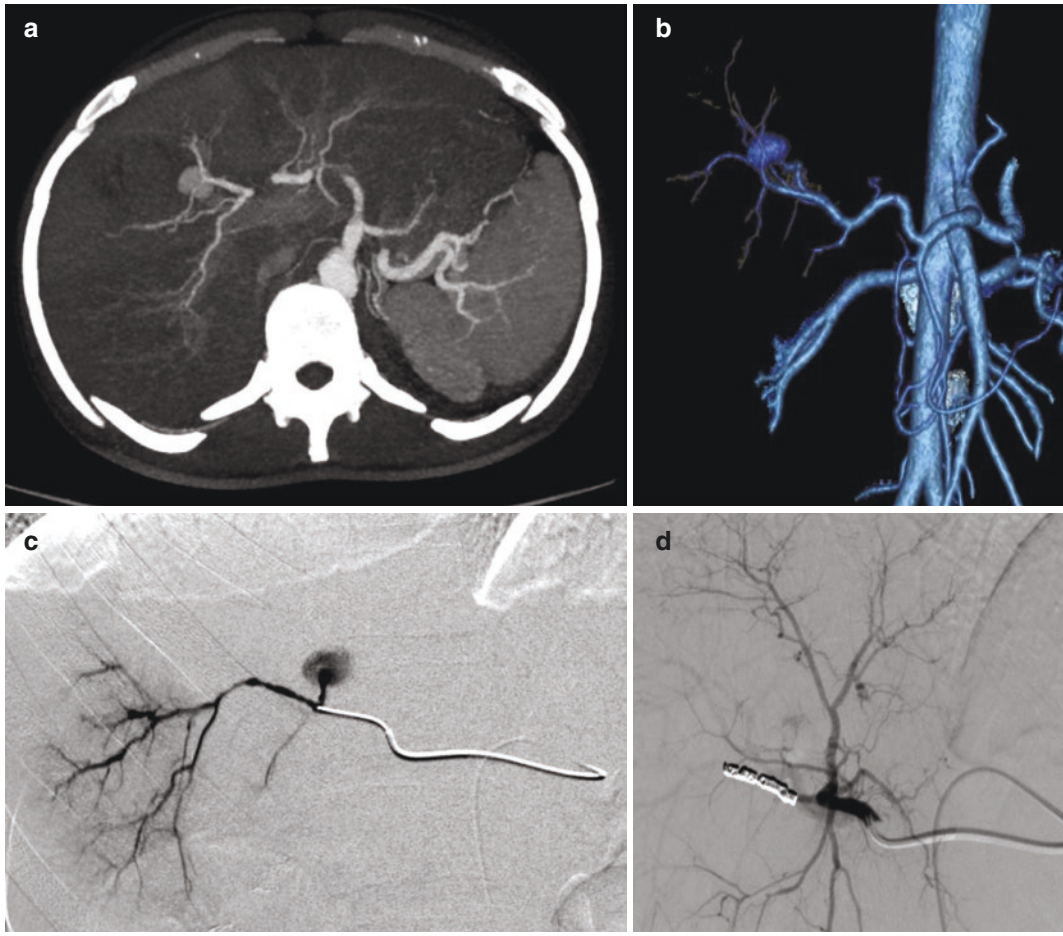

Fig. 6.1 Forty-five-year-old male with history of trauma 1 month back. Presented with melena. CECT revealed AAST 4 injury with right hepatic artery pseudoaneurysm (**a, b**). (**c**) DSA revealed a pseudoaneurysm form right hepatic branch. (**d**) Successfully embolized with coils

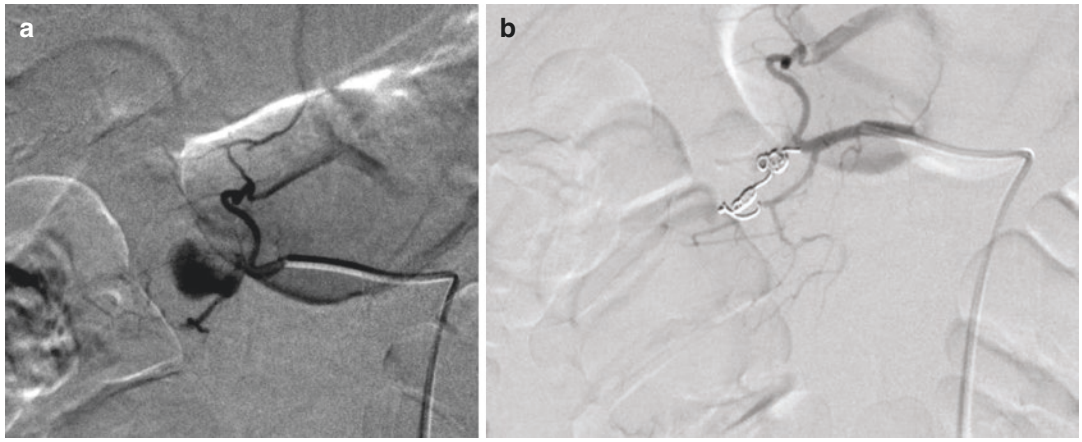

Fig. 6.2 (**a**) Thirty- year-old male with grade III AAST liver injury and segment IVa branch Pseudoaneurysm. (**b**) Embolized with coils

particles, or a little bit of dilute glue (20–25%) (Figs. 6.3, 6.4, 6.5, and 6.6). Making the glue in an appropriate percentage is done by mixing it with lipiodol. Thus, to make 20% glue, 0.5 ml of histoacryl is mixed with 2 ml of lipiodol. The catheter needs to be flushed thoroughly with dextrose and then the glue is injected as the N-BCA polymerizes when it comes in contact with ionic materials like blood and normal saline. In case of a major injury to the liver, where the liver is split across multiple segments and the angiography shows a vascular blush in the region, then the best embolic agent is gelfoam scrapings or slurry injected to ensure that the whole segment is embolized to prevent bleeding.

Once the post-procedure angiograms show no further bleeding, it is important to take another angiogram from a proximal location to ensure that bleeding through a collateral pathway is not present.

6.2.4 Post Procedure

If the patient is hemodynamically unstable, it is advisable to not remove the sheath immediately. It should be kept for 12–24 h, till any bleeding diathesis is corrected. It also allows rapid access to the culprit vessel if there is clinical or radiological evidence of rebleed.

After removal of sheath and compression, immobilization for 6–12 h is advised so that no pseudoaneurysm is formed at the arterial puncture site.

6.2.5 Complications of Embolisation

Other than the standard complications of any angiographic procedure like pseudoaneurysm of the puncture site and dissection or thrombosis, complications specific to hepatic embolization is rarely provided that the portal vein is patent. Rarely, the cystic artery may get embolized leading to gangrene of the gall bladder. It is better to keep the catheter distal to the origin of the cystic artery to prevent it.

6.2.6 Conclusion

Liver injury is not uncommon in polytrauma. CT scanning plays a pivotal role in the diagnosis of hepatic injury and locating the site of active bleeding. Embolisation is a safe and effective way to stabilize such patients.

6.3 Splenic Injury

Spleen is part of the lymphopoietic tissue and constitutes 25% of the total lymphoid tissue in the human body. It is responsible for the opsonization of encapsulated organisms. Spleen is a highly vascular organ which is often a casualty in blunt injury to the abdomen, although it is relatively well protected by the rib cage against penetrative

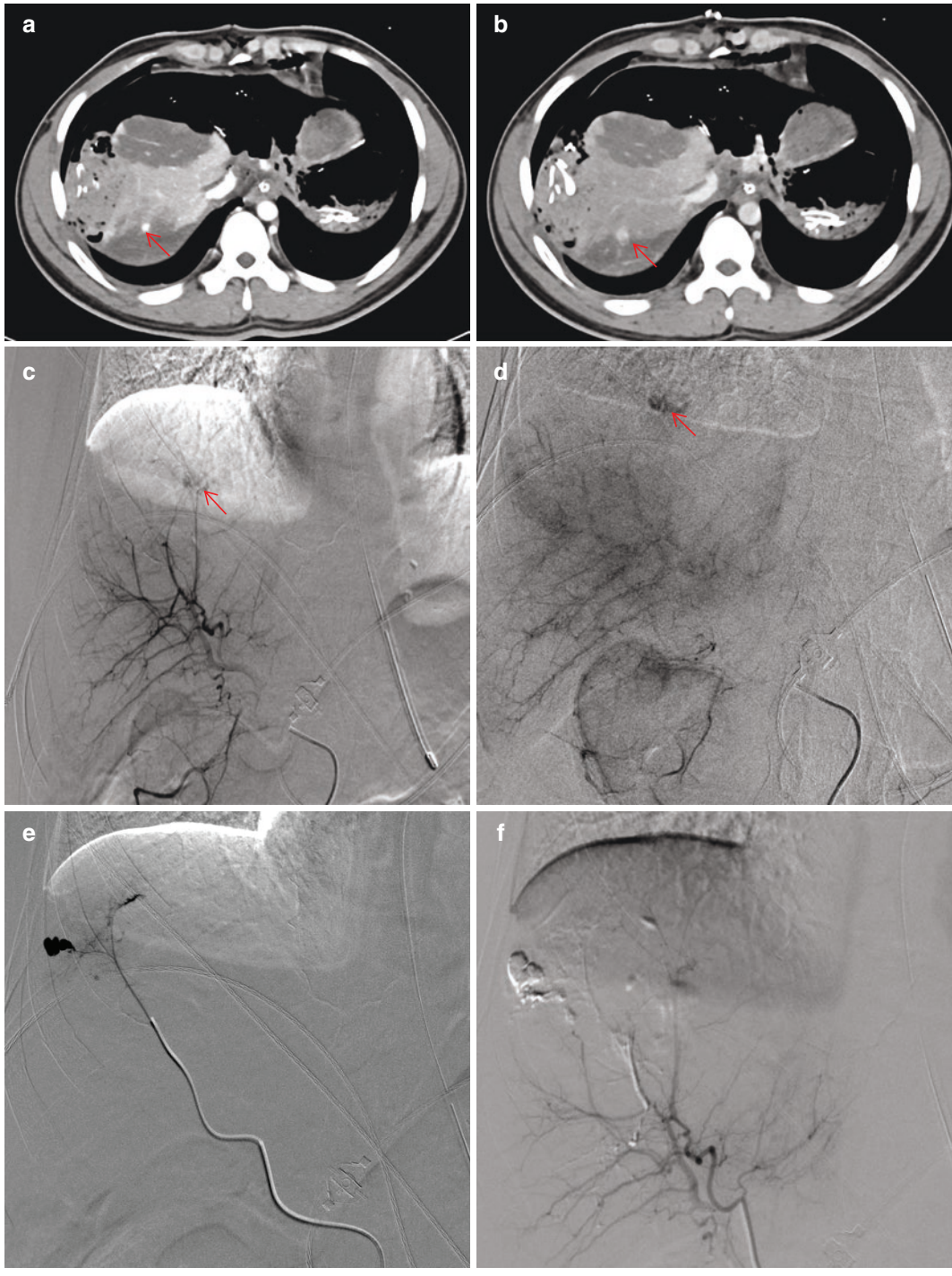

Fig. 6.3 (**a–d**) Active extravasation in segment VII branch (red arrow). (**e**) Selective segment VII injection demonstrating the active extravasation. (**f**) Successfully embolized with glue

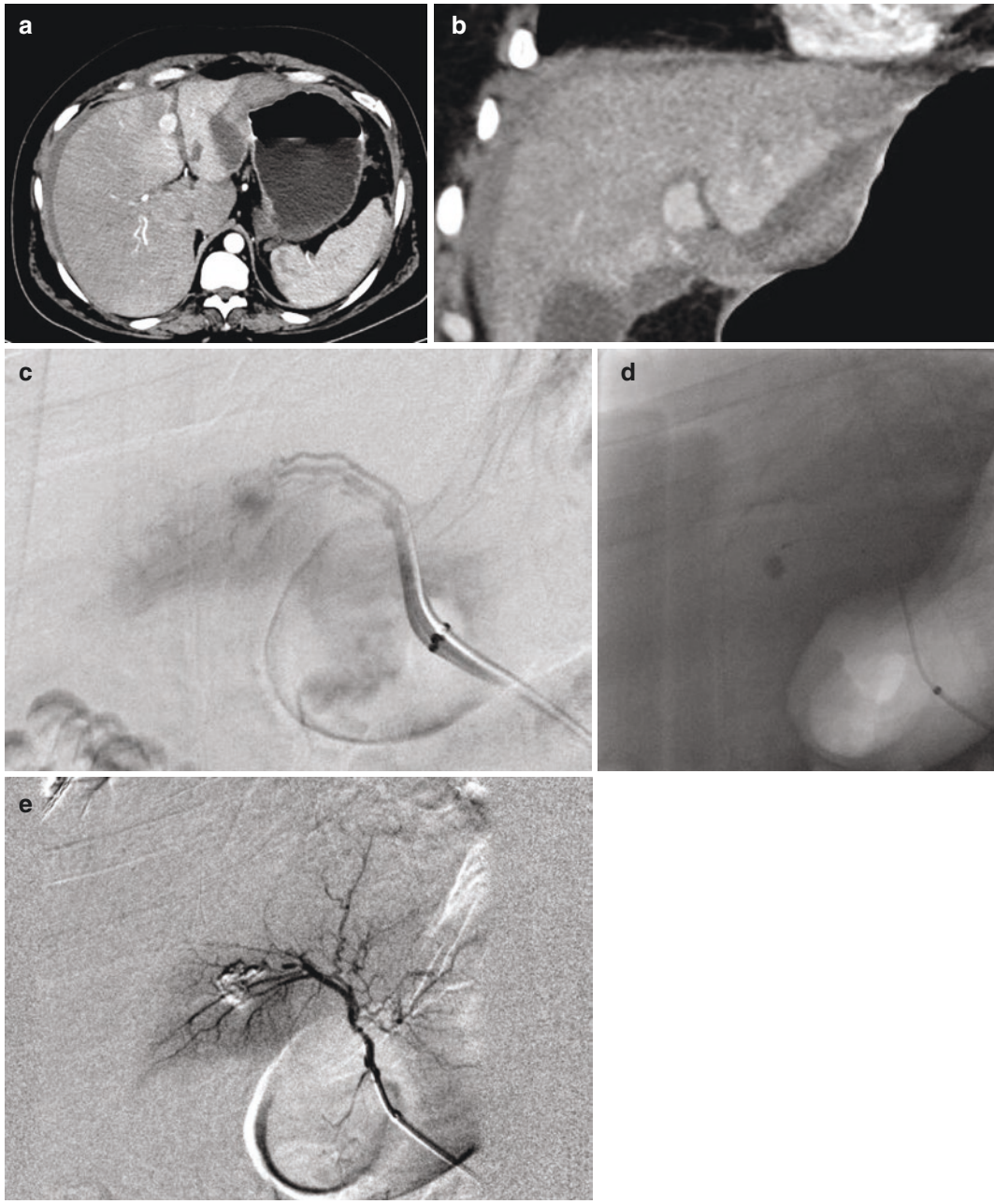

Fig. 6.4 (**a** and **b**) AAST grade II liver injury with Segment IVB pseudoaneurysm. (**c**) Angiography showing pseudoaneurysm in segment III. (**d**) Post-glue embolisation–angiogram shows complete obliteration of the aneurysm

trauma. The foremost concern is to stop ongoing bleeding, even at the cost of losing the organ in the process.

The most common etiological factor is a blunt injury to the abdomen and/or left side of the chest, as in high-velocity trauma or a fall. Penetrating splenic injuries are rare. The other common cause is iatrogenic injury during operative procedures in the abdomen, most commonly distal pancreatectomy or transverse colectomy.

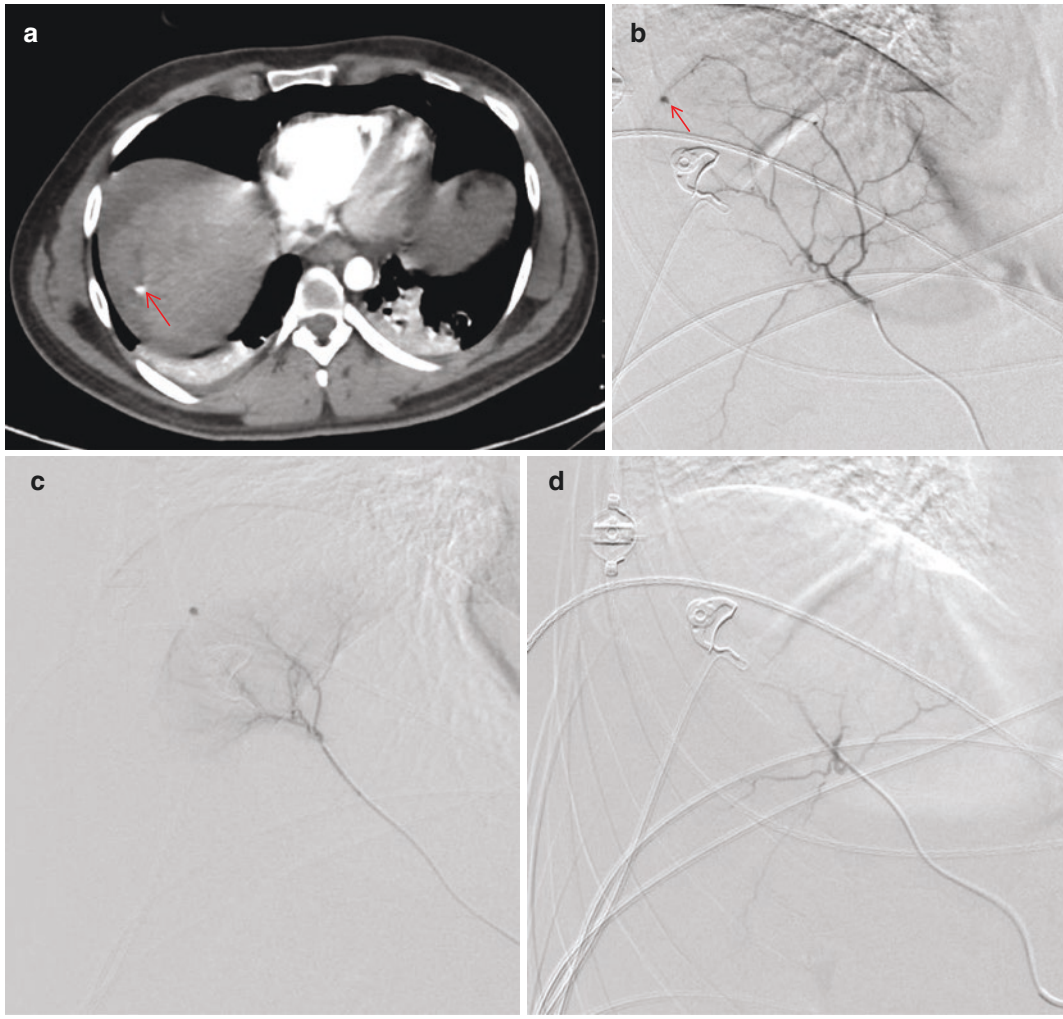

Fig. 6.5 (**a**) CECT showing Pseudoaneurysm in segment VII branch. (**b**) DSA showing Pseudoaneurysm in segment VII branch. (**c**) Selective segment VII hepatic artery angiogram revealing pseudoaneurysm. (**d**) Post embolization with PVA particles (300–500 microns)—complete obliteration of the pseudoaneurysm

6.4 Initial Assessment

Most of these patients are debilitated and unconscious/ intubated at assessment. History is usually not forthcoming. Examination findings include abdominal distention, left upper quadrant or diffuse abdominal tenderness, peritoneal signs, bruises in the left upper quadrant or lower chest, left-sided lower rib fractures. The absence of any abdominal signs does not preclude significant splenic injury. A rapid focused assessment with sonography in trauma (FAST) examination is the most cost-effective and optimal bedside investigation to triage patients with suspected intra-abdominal injury. Detection of free intra-abdominal fluid with positive abdominal signs portends significant organ injury.

6.5 Triage

Management of a patient with splenic injury will depend on a host of factors, the most common being the grade of injury, hemodynamic stability,

and the presence of other life-threatening injuries. FAST positive hemodynamically unstable patients must proceed for an emergency operative procedure which may involve sacrificing the organ. Those that are stable, shall undergo a multiphase contrast CT scan of the abdomen. Imaging in this scenario is helpful in grading the splenic injury as well as identify co-existent solid or hollow viscus injury. The AAST grading scale [9] is widely used to triage the injured patient.

The AAST imaging criteria for splenic injury are as follows:

- Grade I—Subcapsular hematoma <10% surface area. Parenchymal laceration <1 cm in depth. Capsular tear.
- Grade II—Subcapsular hematoma 10 to 50% surface area; intraparenchymal hematoma <5 cm. Parenchymal laceration 1–3 cm in depth.

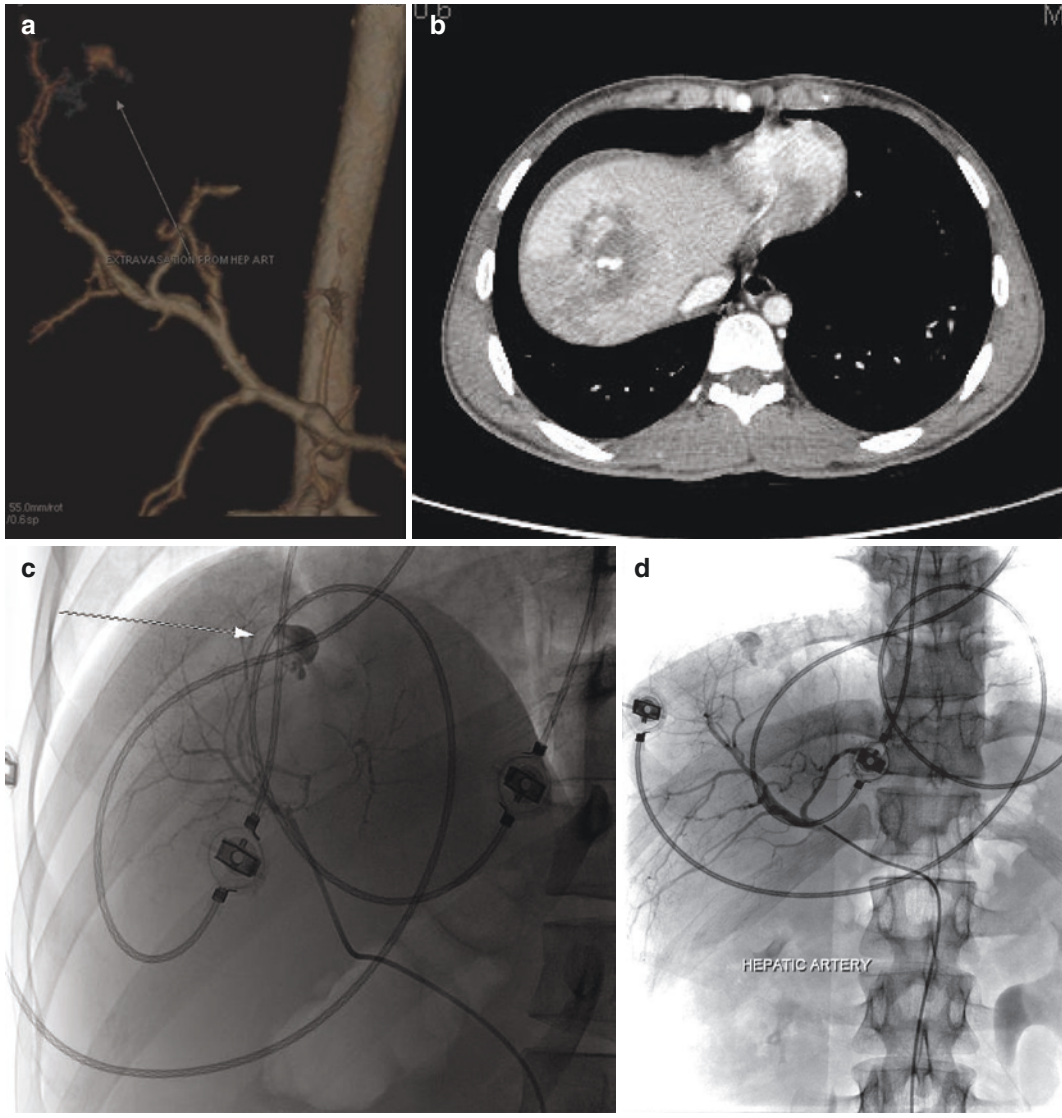

Fig. 6.6 (**a** and **b**) Extravasation from segment VIII branch. (**c** and **d**) Active extravasation from right segment VIII branch

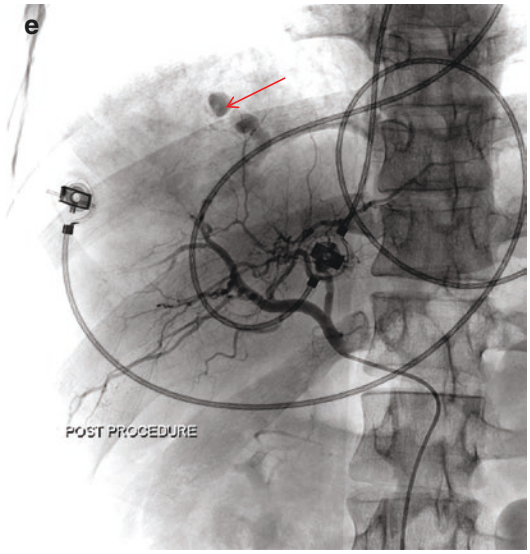

Fig. 6.6 (continued)

- Grade III—Subcapsular hematoma >50% of surface area; ruptured subcapsular or intraparenchymal hematoma ≥5 cm. Parenchymal laceration >3 cm in depth.
- Grade IV—Any injury in the presence of a splenic vascular injury or active bleeding confined within the splenic capsule. Parenchymal laceration involving segmental or hilar vessels producing >25% of devascularization.
- Grade V—Any injury in the presence of splenic vascular injury with active bleeding extending beyond the spleen into the peritoneum. Shattered spleen.

Grade I, II, and III are patients who have non-life-threatening injuries, whereas grades IV and V include those that require operative management more often than not.

6.6 Management

After the completion of imaging, the patient should be triaged to either surgery or nonoperative management with or without embolization. A shattered or devascularized spleen requires splenectomy. Patients with active contrast extravasation and salvageable spleen are candidates for splenic arterial embolization. Rest of the hemodynamically stable patients with grade I to III injury can be observed for a period of 48 to 96 h before discharging from the acute care facility.

Splenic arterial embolization has been proven to be successful in salvaging the spleen and stopping hemorrhage in a high percentage of patients [10]. It avoids the operative procedure and its attendant risks, risk of anesthesia in an acutely sick patient, and risk of post-splenectomy overwhelming sepsis due to encapsulated microbes. In the hands of a trained Interventional Radiologist, this procedure is quick, effective in reliable hemostasis, and relatively complication-free.

Two different techniques of splenic arterial embolization are described in literature [11]. The choice of the technique is most often decided by the imaging and angiographic findings. In cases of focal bleeding demonstrated from an accessible intra-splenic arterial branch on the angiogram, it is preferable to selectively catheterize the culprit branch with a microcatheter through coaxial technique and embolise with 0.018″ coils, particles (PVA, gel foam) or glue, depending on the microcatheter position and technical expertise of the operator (Fig. 6.7). Care should be taken not to miss the short gastric bleeder if the distal splenic angiography is negative, particularly in the context of a CT demonstrated active extravasation. Nonselective, high-quality, breath-hold, digitally subtracted angiograms are necessary for performing this "distal embolization" technique.

If there are multi-site bleeding foci within the spleen, or if a satisfactory angiogram could not be obtained due to technical or patient-related factors, proximal splenic embolization can be performed to obtain control of hemorrhage [12]. It is quick, easy to perform and works by reducing the pressure head on the bleeder(s). The classic site of occlusion is distal to the origin of the dorsal pancreatic artery. The distal splenic vasculature will be collateralized via the short gastric and gastro-epiploic arcades, maintaining tissue perfusion. There is spontaneous cessation of the parenchymal hemorrhage due to reduction in pulse pressure. Preferred embolic agents are vas-

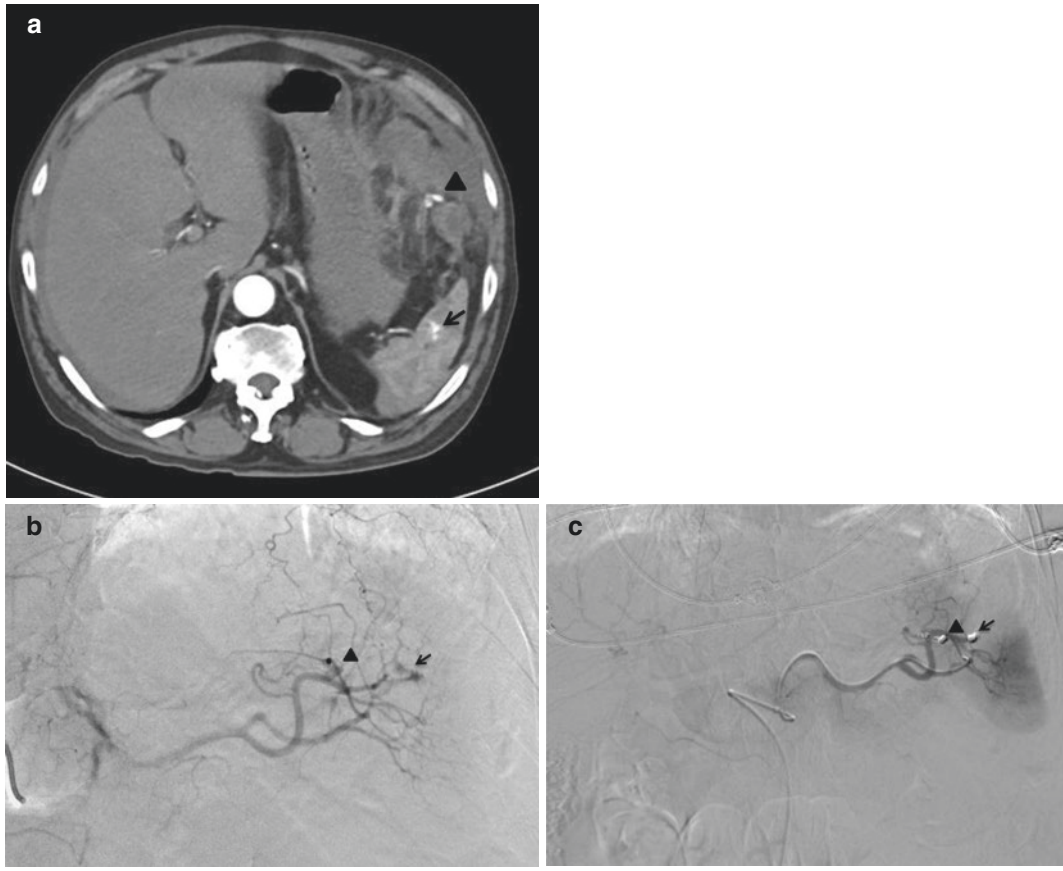

Fig. 6.7 Distal embolization in grade 3 stable splenic injury. (**a**) Axial arterial phase contrast CT showing two sites of extravasation in the spleen and lesser sac from the splenic (arrow) and left gastric (arrow head) arteries, respectively. (**b**) Splenic artery digital subtraction angiogram (DSA) showing active extravasation at the two sites (arrow head and arrow). (**c**) DSA post super-selective embolization with 0.018″ fibered coils (arrow head and arrow) through a Progreat (Terumo) microcatheter

cular plugs (Amplatz plugs II and IV), 0.035″ fibered coils, or sometimes concentrated glue. Sometimes a combination of both techniques (proximal and distal) is needed to control the hemorrhage (Fig. 6.8).

Complications due to the procedure include puncture site bleeding/ pseudoaneurysm, splenic infarction, and abscess formation or loss of splenic function. Major adverse events are rare in cases of proximal splenic artery embolization as compared to distal embolization, as collaterals preserve the parenchyma and function. There are no standardized guidelines on post-procedure antibiotic prophylaxis or immunization.

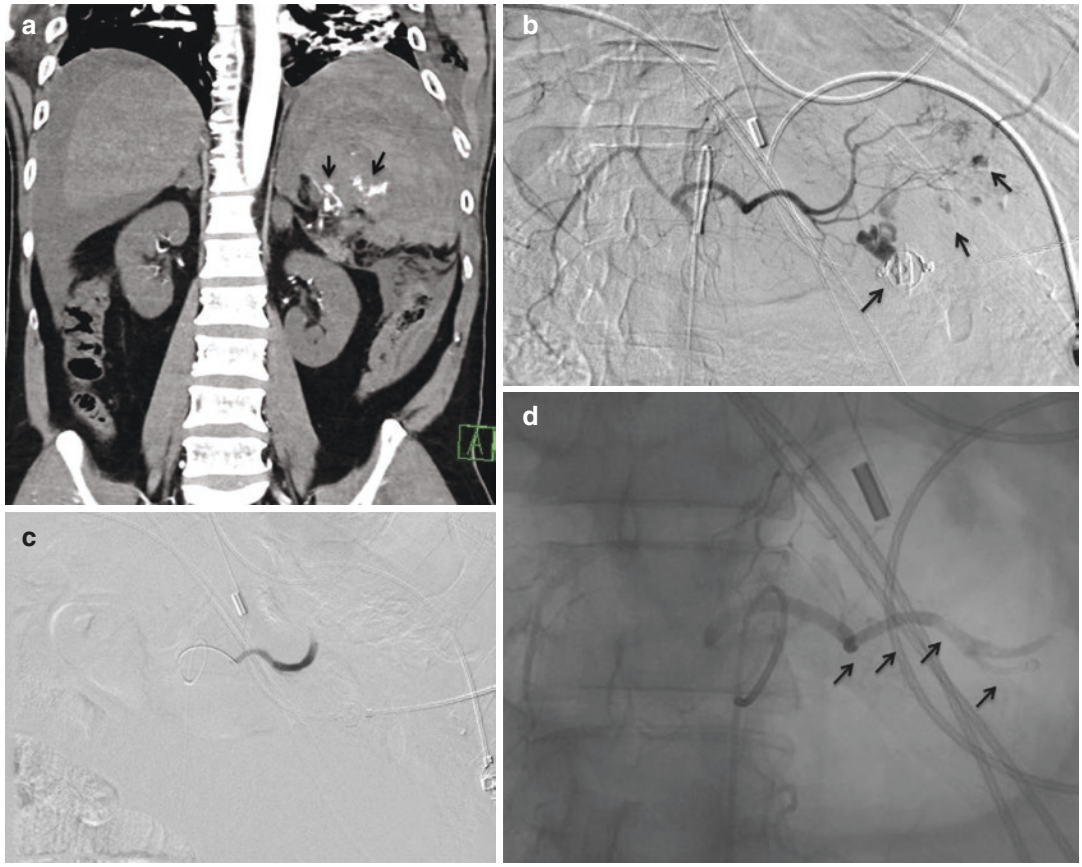

Fig. 6.8 Proximal and distal embolization in a patient with grade 5 splenic injury (**a**) Coronal arterial phase CT showing shattered spleen with multifocal extravasation (arrows). (**b**) Splenic artery DSA showing multifocal extravasation (arrows) from splenic arterial branches. (**c**) DSA post 300–500 micron PVA particle embolization shows stasis in the main splenic artery. (**d**) Fluoroscopy image after 50% Glue embolization (arrows) of the splenic artery distal to the dorsal pancreatic artery

References

1. WSES classification and guidelines for liver trauma. World J Emerg Surg. Full Text [Internet]. [cited 2019 Jul 4]. Available from https://wjes.biomedcentral.com/articles/10.1186/s13017-016-0105-2
2. Wooster M, Spalding MC, Betz J, Sellers S, Moorman M, O'Mara MS. Non-operative management of blunt hepatic injury: early return to function, chemical prophylaxis, and elucidation of Grade III injuries. International Journal of Academic Medicine. 2018;4(3):271.
3. Chatoupis K, Papadopoulou G, Kaskarelis I. New technology in the management of liver trauma. Ann Gastroenterol. 2013;26(1):41–4.
4. Coccolini F, Montori G, Catena F, Di Saverio S, Biffl W, Moore EE, et al. Liver trauma: WSES position paper. World J Emerg Surg [Internet]. 2015 Aug 25 [cited 2019 Jul 15];10. Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4548919/
5. Xu H, Jie L, Kejian S, Xiaojun H, Chengli L, Hongyi Z, et al. Selective angiographic embolization of Blunt hepatic trauma reduces failure rate of nonoperative therapy and incidence of post-traumatic complications. Med Sci Monit. 2017 Nov 20;23:5522–33.
6. Sivrikoz E, Teixeira PG, Resnick S, Inaba K, Talving P, Demetriades D. Angiointervention: an independent predictor of survival in high-grade blunt liver injuries. Am J Surg. 2015 Apr;209(4):742–6.
7. Schuster T, Leissner G. Selective angioembolization in blunt solid organ injury in children and adolescents: review of recent literature and own experiences. Eur J Pediatr Surg. 2013 Dec;23(6):454–63.
8. Vascular and biliary variants in the liver: Implications for liver surgery. Radio Graphics [Internet]. [cited

2019 Jul 4]. Available from https://pubs.rsna.org/doi/full/10.1148/rg.282075099
9. Kozar RA, et al. Organ injury scaling 2018 update: spleen, liver, and kidney. J Trauma Acute Care Surg. 2018;85(6):1119–22.
10. Imbrogno B, Ray C. Splenic artery embolization in Blunt trauma. Semin Interv Radiol. June 2012;29(02):147–9.
11. Rong J-J, et al. The impacts of different embolization techniques on splenic artery embolization for Blunt splenic injury: a systematic review and meta-analysis. Mil Med Res. Dec. 2017;4(1):17.
12. Quencer KB, Smith TA. Review of proximal splenic artery embolization in Blunt abdominal trauma. CVIR Endovascular. Dec. 2019;2(1):11.

IR Management of Hemobilia

7

Ujjwal Gorsi

7.1 Introduction

Hemobilia is the presence of blood in the lumen of the biliary tree and commonly results from fistulous communication between the biliary ductal system and hepatic vasculature. It is an uncommon, nevertheless important cause of gastrointestinal bleeding and can be fatal if not recognized and treated in time.

Hemobilia was reported first by Francis Glisson in 1654 who reported fatal biliary bleeding one week after a liver laceration sustained during a sword fight [1]. Philip Sandblom coined the term hemobilia in 1948 [2].

Clinically patients may present with abdominal pain, melena, hematemesis, and jaundice. Iron deficiency anemia may be the presenting feature if the bleeding is minor but chronic. Clinical trial of upper abdominal pain, jaundice, and upper GI bleeding is known as Quincke's triad and points towards the biliary tract as source of bleeding [3]. All these three symptoms, however, are present in a minority of patients, i.e., between 22% to 35% [4].

7.2 Etiologies and Mechanism of Hemobilia

Majority of cases of hemobilia now occur as a result of invasive percutaneous radiological and endoscopic interventions. Hemobilia resulting from these procedures involving the hepatopancreatobiliary system has superseded trauma which used to be the most common etiology of hemobilia until recently [5, 6]. Main etiologies of hemobilia are listed in Table 7.1 Hemobilia is responsible for 3% of major complications of percutaneous liver biopsy [7]. The presence of chronic portal vein thrombosis specially if associated with presence of portal cavernoma or collateral vessels has higher risk for this complication to occur [6, 8]. Percutaneous transhepatic biliary drainage (PTBD) has a higher rate of hemobilia as compared to percutaneous transhepatic cholangiography (PTC) with one study reporting rate of 2.2% in PTBD vs 0.7% in PTC. This increase in risk of hemobilia is considered secondary to both the larger size of the opening made in the bile duct in PTBD and also due to the continuous presence of foreign body which may incite inflammation and subsequent erosion of adjacent vasculature. Non-dilated biliary system may also be associated with higher chances of hemobilia [6, 8].

Endoscopic retrograde cholangiopancreatography (ERCP) is the most common endoscopic procedure accounting for hemobilia. Chances of

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Table 7.1 Etiologies of hemobilia

Percutaneous transhepatic cholangiography (PTC), percutaneous liver biopsy and percutaneous transhepatic biliary drainage (PTBD)
Transjugular intrahepatic portosystemic shunt
ERCP, especially when accompanied by sphincterotomy
EUS-guided fine needle aspiration or biopsy
EUS-guided choledochoduodenostomy and hepaticogastrostomy
Blunt hepatic trauma
Liver transplantation, cholecystectomy(open and laparoscopic) and pancreaticoduodenectomy
Radiofrequency ablation (RFA) for HCC
Cholangiocarcinoma, pancreatic adenocarcinoma, gall bladder carcinoma, HCC, and metastatic lesions to the liver
Portal biliopathy
Chronic duct obstruction
Intraductal infections

it increase significantly if associated with sphincterotomy. An important emerging cause of hemobilia is endoscopic ultrasound-guided procedures [6, 9]. Surgeries like cholecystectomy (both open and laparoscopic), pancreaticoduodenectomy and liver transplant can be complicated by hemobilia with injury to right hepatic artery and cystic artery being the most common cause [10–12].

Hepatobiliary malignancies are responsible for 10% of all hemobilia cases. Increased vascular supply in friable tissue of malignancy is thought to be the cause of hemorrhage in these tumors [7].

In addition, portal hypertensive biliopathy, chronic duct obstruction, and intraductal infection due to parasitic infestation of the biliary system, i.e., Chinese liver fluke (*Clonorchis sinensis*), roundworms (e.g. *Ascaris lumbricoides*), sheep liver fluke (*Fasciola hepatica*) and Echinococcal infections are considered important causes of hemobilia [6].

The onset of hemobilia after trauma or an interventional procedure is variable. Hemobilia commonly occurs within 4 weeks of bile duct injury. ERCP-related hemobilia may occur immediately after or within few days of the procedure. Causes of delayed onset of hemobilia are slowly expanding pseudoaneurysm, bile stasis, and hepatic necrosis [9, 13] Hemobilia is commonly due to biliary-arterial communication as there is high pressure differential between branches of hepatic artery and bile ducts. On the other hand, there is low pressure gradient between biliary-venous communications hence such bleeds tend to cease spontaneously unless accompanied by portal hypertension [9, 14].

Due to difference in density and biochemical properties between bile and blood, a distinct separation of two is created with in the biliary ductal system irrespective of location of haemorrhage. Frequently it results in formation of intraductal clots which acts as a physical barrier to smooth biliary flow. These clots over time cause stasis of bile and may lead to acute cholangitis clinically manifesting as a right upper quadrant or epigastric pain [9, 15].

7.3 Diagnosis

Typical clinical features along with history of recent instrumentation can help in arriving at a correct diagnosis. Standard protocol for upper GI bleeding starting with endoscopy is followed if suspicion of hemobilia is low. At endoscopy, the source of bleeding can be localized to the biliary system if blood or clot can be seen coming out of the papilla or if fresh blood is present in the second portion of the duodenum [6, 9].

If endoscopy is nondiagnostic, CT Angiography (CTA) is routinely ordered next. Findings seen in cases of hemobilia are active contrast extravasation from culprit artery, pseudoaneurysms, arteriovenous fistulas, or vascular malformations. Biliary ductal dilatation, thrombus, or calculi within bile ducts or the gallbladder may also be noticed. Features of blunt hepatic trauma or presence of hepatobiliary malignancy are usually apparent on CT. CTA also has valuable role in planning endovascular interventions as it provides road map for the same specially when surgically altered anatomy such as with transplanted livers is encountered [9].

7.4 Management

Management of hemobilia consists of two components. Haemostasis has to be achieved quickly and bile flow has to be maintained. Maintaining bile flow and resorting to uninterrupted bile flow is important in management of hemobilia as the presence of blood clots with in biliary tree can cause obstructive jaundice and acute cholangitis. Acute cholecystitis and acute pancreatitis have also been reported [9]. Hemobilia can be minor or major and interventional.

Radiologists play an important role in managing both of these types.

7.4.1 Minor Hemobilia

Minor hemobilia clinically can present either as small drop of hemoglobin or blood-tinged bile from a PTBD catheter. Liver function tests may be normal or show transient abnormality. Bleeding in these cases usually result from venous injury either during needle placement or during dilatation of track. Local tissue irritation can also lead to minor hemobilia. In cases where PTBD catheter is in situ, simple maneuvers by interventional radiologist like adjusting catheter position such that its side holes are not adjacent to site of suspected venous transgression or exchanging the PTBD catheter with a larger diameter catheter will resolve minor hemobilia as a result of the tamponading effect. When due to PTBD insertion, minor hemobilia usually settles when the catheter tract gets matured and if underlying coagulopathy if any is corrected [6].

7.4.2 Major Hemobilia

Major hemobilia is defined as bleeding which is associated with persistent hemorrhage and significant hemoglobin drop despite the best supportive care. It is often dealt with vascular radiological interventions. Surgery may be required in rare instances. Patients with hemodynamic instability should be taken directly to interventional radiology suite as arterial bleed is the usual cause. Patients with persistent /recurrent hemobilia due to arterial sources identified either on endoscopy or imaging are also taken for endovascular procedures.

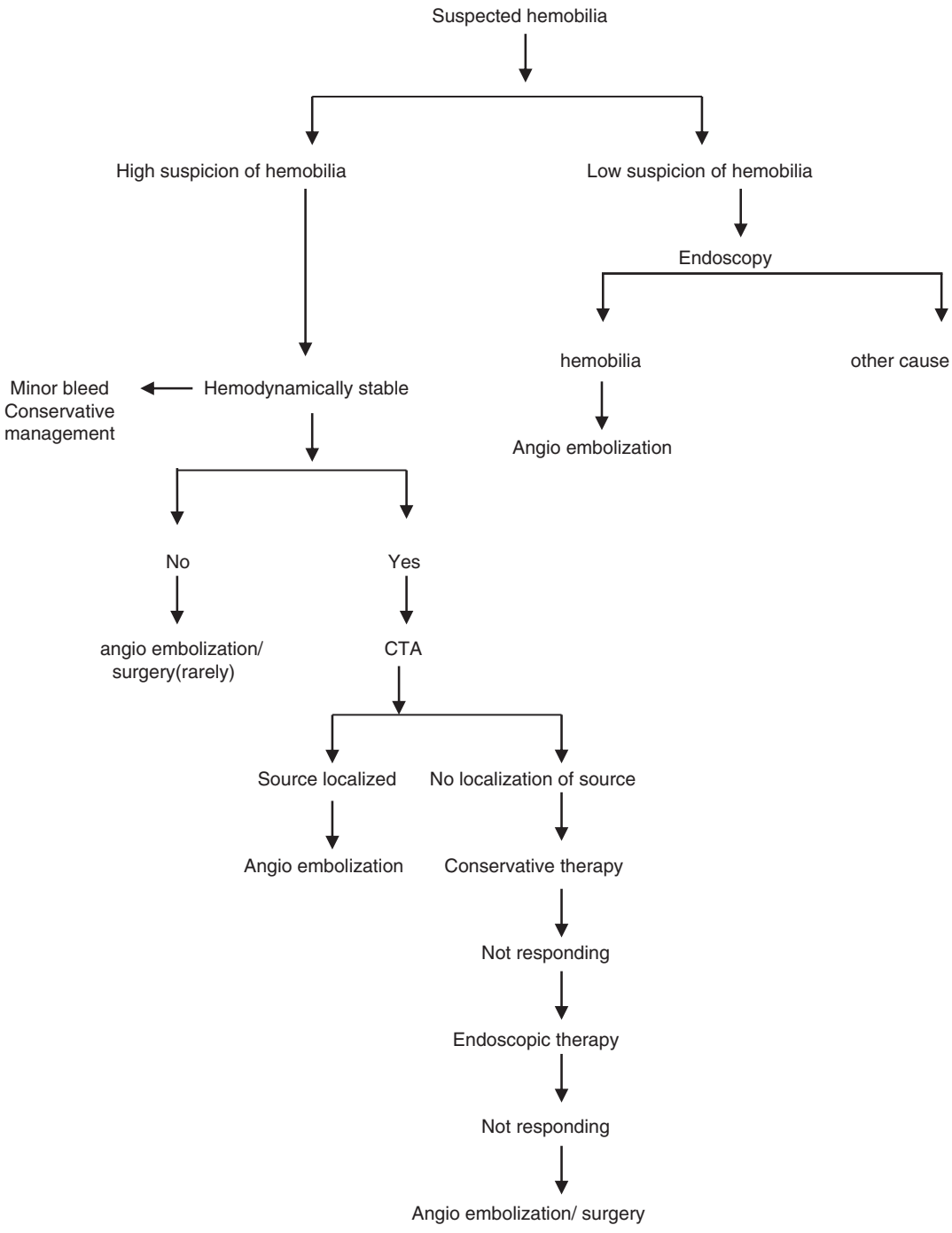
An algorithm followed in our institute for suspected hemobilia is given in Flowchart 7.1. Details of hardware required for interventional radiology management of hemobilia are given in Table 7.2.

7.5 Endovascular Techniques in Management of Hemobilia

7.5.1 Embolization

Embolization is the cornerstone in managing patients who present with major hemobilia or persistent minor hemobilia if source of bleed is suspected to be arterial [5]. Embolization of branches of hepatic artery can safely be done without significant concern for ischemic complications due to unique dual blood supply of liver (25% via hepatic artery and 75% via portal vein). Only notable exceptions to this rule being liver transplant patients and the patients who have portal vein thrombosis [9] Standard pre-procedural preparation and contraindications for catheter-directed angiography are applied [16]. The femoral arterial access is the preferred route. Brachial or axillary approaches are rarely needed. Catheter most commonly used for cannulating celiac axis at our institute is Cobra catheter. For difficult cannulations, we resort to reverse curve catheters like Simmons.

A celiac arteriogram is performed to delineate the hepatic arterial anatomy. Delayed imaging is done to look for patency of the portal vein if CECT was not acquired prior to embolization. Selective cannulation of the common hepatic, proper hepatic, right and left hepatic arteries is done if no culprit source is identified on celiac arteriography. Any vessels along the path of the biliary drain should be interrogated. If still no obvious bleeder is identified, PTBD catheter can be removed over a guidewire. This maneuver may unmask tamponade effect of catheter and reveal previously obscured bleeder [9]. Superior mesenteric artery is also interrogated to exclude any bleeder arising from accessory/replaced right hepatic artery.



Flowchart 7.1 Algorithm for managing patients with suspected hemobilia

Table 7.2 Hardware required for interventional radiology management of hemobilia

1	18G puncture needle
2	Arterial sheath (5F or 6F, 11 cm) for initial access. Bigger sizes and lengths needed if stenting is planned
3	Hydrophilic guide wire– 0.035″-150 cm
4	Diagnostic catheters. E.g., C1, C2, SIM1-5F
5	Microcatheter
6	Push able microcoils usually 0.018″
7	Detachable coils
8	nBCA glue
9	Lipiodol
10	Stent grafts
11	Thrombin

Angiographic findings of hemobilia include active contrast extravasation into the biliary tree or the parenchyma. Other signs like pseudoaneurysm, vessel irregularity, vessel spasm, and its abrupt cut off or arteriovenous fistula may also be seen [17]. Hemobilia can occasionally be intermittent and may be missed on angiography.

Once the site of the bleeding is identified, super-selective catheterization with a microcatheter followed by embolization is recommended.

Embolization is most commonly done using microcoils. Pseudoaneurysms should be embolized with coils from distal to proximal across the neck (Fig. 7.1) to prevent its refilling from collaterals. Coils are usually 20% oversized relative to the vessel to prevent their migration. Pushable microcoils are usually preferred as they are easy to use, cheap, and have proven efficacy. In some cases, coils may need to be supplemented by either gelfoam or polyvinyl alcohol (PVA) particles to achieve hemostasis. In cases where artery bearing pseudoaneurysm cannot be sacrificed (e.g., transplant liver) and if the pseudoaneurysm has favourable anatomy (with narrow neck), these pseudoaneurysms can directly be cannulated, and embolized using detachable coils. The detachable coils can be implanted precisely and can also be withdrawn if not placed satisfactorily.

Liquid embolic agents (n-BCA or Onyx) are useful in situations when extremely tortuous arterial anatomy is encountered (Fig. 7.2), when source of bleed cannot be reached due to small calibre of culprit artery or when a pseudoaneurysm is fed by multiple arterial branches. These agents have the advantage of occluding branches distal to the neck of pseudoaneurysm without having needed to cross the neck. Another major advantage is potential to be used in coagulopathic patients in which other embolic agents may fail to achieve hemostasis.

Liquid embolic agents, however, require greater skills and experience as reflux into nontarget vessels can cause inadvertent ischemia [18]. Adherence of the catheter to glue may also occur. Glue is mixed with lipiodol before injection to adjust the rate of polymerization as well as to aid in its visualization. The amount of glue lipiodol mixture injected will depend upon the flow dynamics, dead space of microcatheter, and size of culprit artery and size of the pseudoaneurysm. Using higher frame rate, test injection with contrast, giving injection slowly to prevent reflux, immediate withdrawal of microcatheter after injection, and immediate aspiration of residual glue through diagnostic catheter can help reducing the complications.

Gelfoam and PVA particles either alone or in combination are usually used as embolic agents when tumours are the cause of hemobilia. Selective cannulation of culprit arteries limits the chances of nontarget embolization. Gelfoam and PVA particles are mixed with appropriately diluted contrast to render them radio opaque.

Empirical embolization of the branches of hepatic artery supplying the probable area of concern is usually not advised even with normal portal vein. Complications such as hepatic necrosis and abscess formation and delayed complications like biliary stenosis have been described as a result of hepatic arterial embolization. Biliary strictures occur because the bile ducts are supplied primarily by hepatic artery branches rather than portal venous branches. If bleeding source is identified but selective embolization cannot be performed in cases of massive life-threatening hemobilia, nonselective

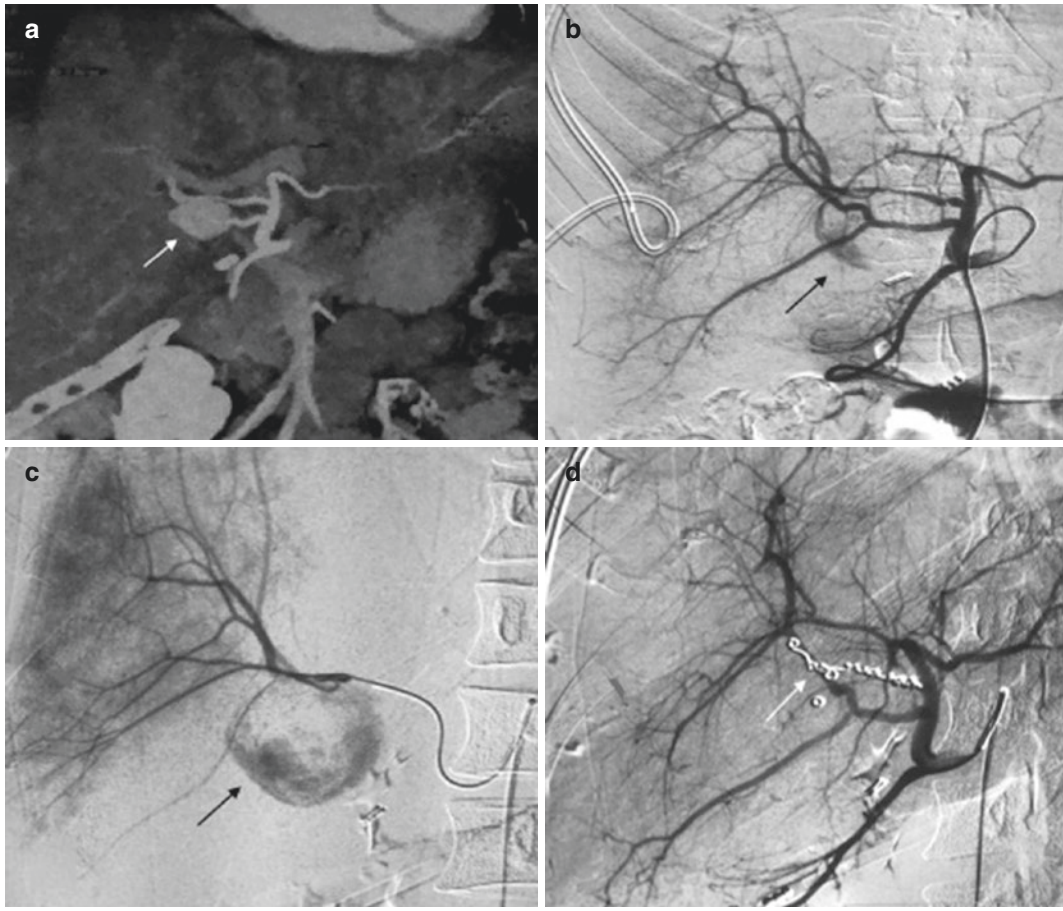


Fig. 7.1 Post-cholecystectomy hemobilia. (**a**) Coronal reformatted CECT image shows a large pseudoaneurysm arising from RHA (arrow). (**b**) Selective angiogram of common hepatic artery and (**c**) Right hepatic artery shows Pseudoaneurysm (arrow in **b** and **c**) arising from right hepatic artery. (**d**) Post-coil embolization angiogram of common hepatic artery shows obliteration of pseudoaneurysm (arrow). Coiling is to done across the neck of pseudoaneurysm to avoid refilling by collaterals

embolization of the right or left hepatic artery may be considered with increased risk of impairment of liver function [9].

Endovascular therapy is technically successful in 75% to 100% of cases of hemobilia [4]. Treatment failure is due to the inability to find bleeder on angiography or missed collaterals.

7.5.2 Stent Placement

Placement of a covered stent across the site of bleed is an attractive alternative to embolization. Preservation of distal flow is extremely beneficial in cases in which embolization of hepatic artery can lead to severe ischemic complications like in patients with portal vein thrombosis and liver transplant patients. Balloon-expandable coronary stent grafts can be used in stenting small segmental hepatic arterial branches as they are similar in size to coronary arteries. The stent diameter is oversized by 10% to 20% and the extending 10 mm on either side of site of leak is recommended [19].

In addition, covered stent can also be used for treating pseudoaneurysms arising from a hepatic artery if they have straight course. Flow diverters are self-expandable, uncovered stents with mul-

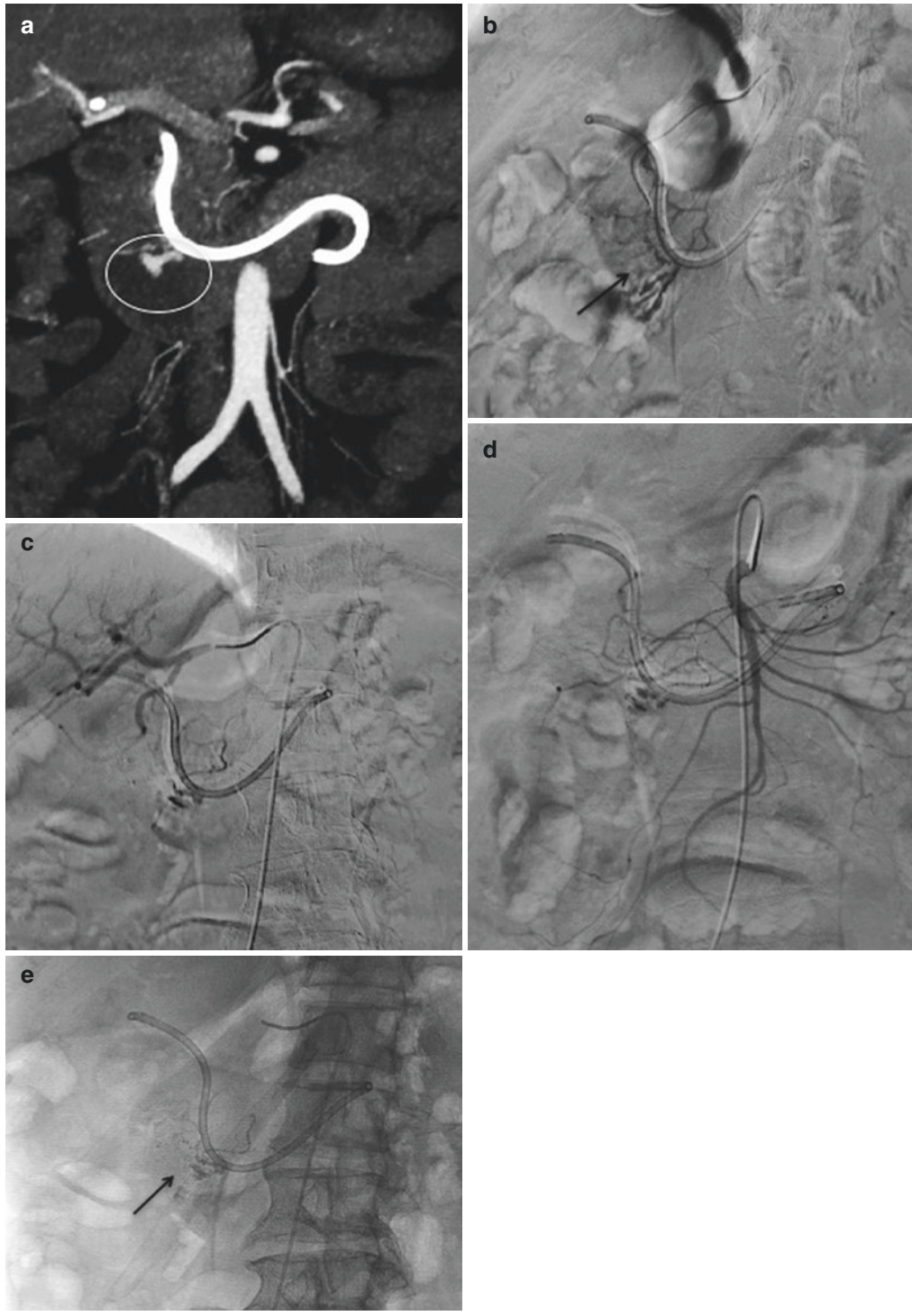


Fig. 7.2 Post-ERCP assisted CBD stenting, massive hemobilia. (**a**) Coronal reformatted CECT image shows active contrast extravasation into the second part of duodenum (circle). (**b**) Selective angiogram of gastro duodenal artery shows tortuous narrow caliber branches with active contrast extravasation(arrow). (**c**) Post-endovascular glue embolization, common hepatic artery angiogram shows cessation of active bleed. (**d**) Superior mesenteric artery angiogram ruled out any refilling from collaterals. (**e**) Fluoroscopy image showing glue cast (arrow)

tiple layers which modulate the blood flow leading to a decrease in the velocity and turbulence in the pseudoaneurysm leading to its gradual thrombosis. These stents have successfully been used in the treatment of hepatic artery pseudoaneurysms [20, 21]. Antiplatelet therapy is routinely prescribed after covered or flow diverter stent insertion. Clopidogrel (75 mg/day) for 4–6 weeks and lifelong aspirin (75–100 mg/day) are the commonly used drugs.

In cases of portal biliary fistula which fail to resolve spontaneously, stent placement within the biliary system, rather than portal venous system may be considered. Stent graft can be placed with in biliary system through existing PTBD tract or through endoscopy. It obviates the challenge of accessing the portal venous system and is usually successful [9].

7.6 Percutaneous Techniques in Management of Hemobilia

7.6.1 Percutaneous Thrombin Injection

Percutaneous thrombin injection (PTI) is also an option for cases of hemobilia secondary to hepatic artery pseudoaneurysm. The most common reason for resorting to percutaneous thrombin injection in our practice is failure to assess culprit artery via endovascular route. Though in some cases, if suitable anatomy is there and pseudoaneurysm is well visualized on USG we directly embolize pseudoaneurysms under USG guidance without considering endovascular route (Fig. 7.3). Targeted pseudoaneurysms should have a narrow neck to avoid distal embolization.

Under ultrasound guidance, a 22-gauge needle is advanced into the pseudoaneurysm and reconstituted thrombin (500 IU/ml or 1000 IU/ml) is slowly injected using real-time colour Doppler to assess flow cessation. In most of the cases, pseudoaneurysm gets thrombosed within seconds of injecting thrombin. We follow these pseudoaneuryms with USG and colour Doppler 24 hours post-procedure and then a week later to asses for recanalisation which may happen occasionally.

Percutaneous thrombin injection is quicker, cheaper, and less invasive though complications like nontarget embolization, bleeding as a result of needle placement may occur [9].

7.6.2 Percutaneous Glue Injection

Percutaneous glue injection is another option for cases of hemobilia secondary to hepatic artery pseudoaneurysms and has also been used as a primary treatment to treat such pseudoaneurysms [22]. Percutaneous glue injection can be considered if pseudoaneurysm meets the following criteria: the presence of favourable neck-to-dome ratio (<1), favourable anatomical location for percutaneous needle placement with minimal risk of injury to major vessels and lack of arteriovenous fistulous communication [22]. Pseudoaneurysms arising from arteries which cannot be assessed via endovascular route can be embolized by percutaneous glue injection (Fig. 7.4).

A 1:1 mixture of n-Butyl cyanoacrylate (nBCA) and lipiodol to attain 50% concentration of glue mixture is prepared followed by placement of 22G spinal needle within the pseudoaneurysm sac under colour doppler guidance. After placing the needle, it is flushed with 5% dextrose solution and glue mixture is injected slowly under fluoroscopy guidance until glue cast is seen completely filling the pseudoaneurysm sac [22].

7.7 Choice of Embolizing Agent in Specific Situations

If the culprit vessel is end artery and can be reached super selectively, the choice of embolising agent is coil. If coil embolization alone fails to achieve hemostasis, the embolizing effect is supplemented by either gelfoam or PVA or glue as sandwich technique. If the pseudoaneurysm is arising from major artery like common hepatic artery, choice would either be stent graft or embolizing the pseudoaneurysm sac with detachable coils or glue [23]. If hemobilia is due to tumours, gelfoam and/or PVA embolization is done to

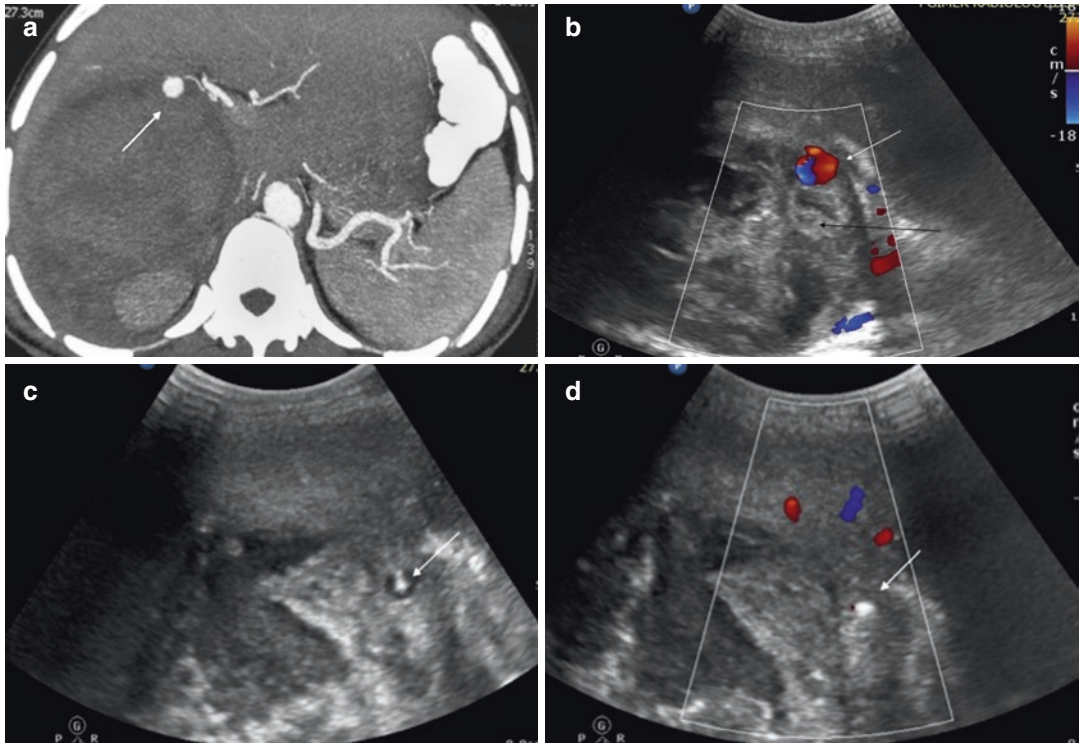


Fig. 7.3 Blunt trauma abdomen with grade IV liver injury and hemobilia. (**a**) Axial CECT image showing pseudoaneurysm in relation to right hepatic artery (arrow) anterior to a large hematoma. (**b**) On colour doppler, pseudoaneurysm with yin-yang sign is seen. (**c**) Percutaneous thrombin into pseudoaneurysm injected using 22 G spinal needle. Echogenic needle tip is seen with in the sac of pseudoaneurysm (arrow). (**d**) Post-thrombin injection, no colour filling is seen (arrow). No recanalization was seen on Doppler done on subsequent days (not shown)

achieve hemostasis. If the pseudoaneurysm cannot be accessed via endovascular route, direct percutaneous thrombin or percutaneous glue injection can be considered.

7.8 Results

As hemobilia is a rare condition, only few studies have evaluated the success of endovascular interventions and have shown good technical and clinical outcomes with transarterial embolization [17, 23]. Data regarding the use of stents and flow diverters is limited to small case series [20, 21] and has shown good results so far. Use of percutaneous thrombin and percutaneous glue injections is limited to few cases reports only though have shown encouraging results [22].

7.9 Post-Procedure Management

Routine post-angiography and puncture site management are advised. Vital signs and hemoglobin monitoring should be looked for as persistent hypotension or tachycardia could be signs of ongoing hemorrhage and may require repeat endovascular/surgical management. Post-embolization syndrome in the form of abdominal discomfort, pain, and mild fever can be seen in most of patients. These symptoms are usually

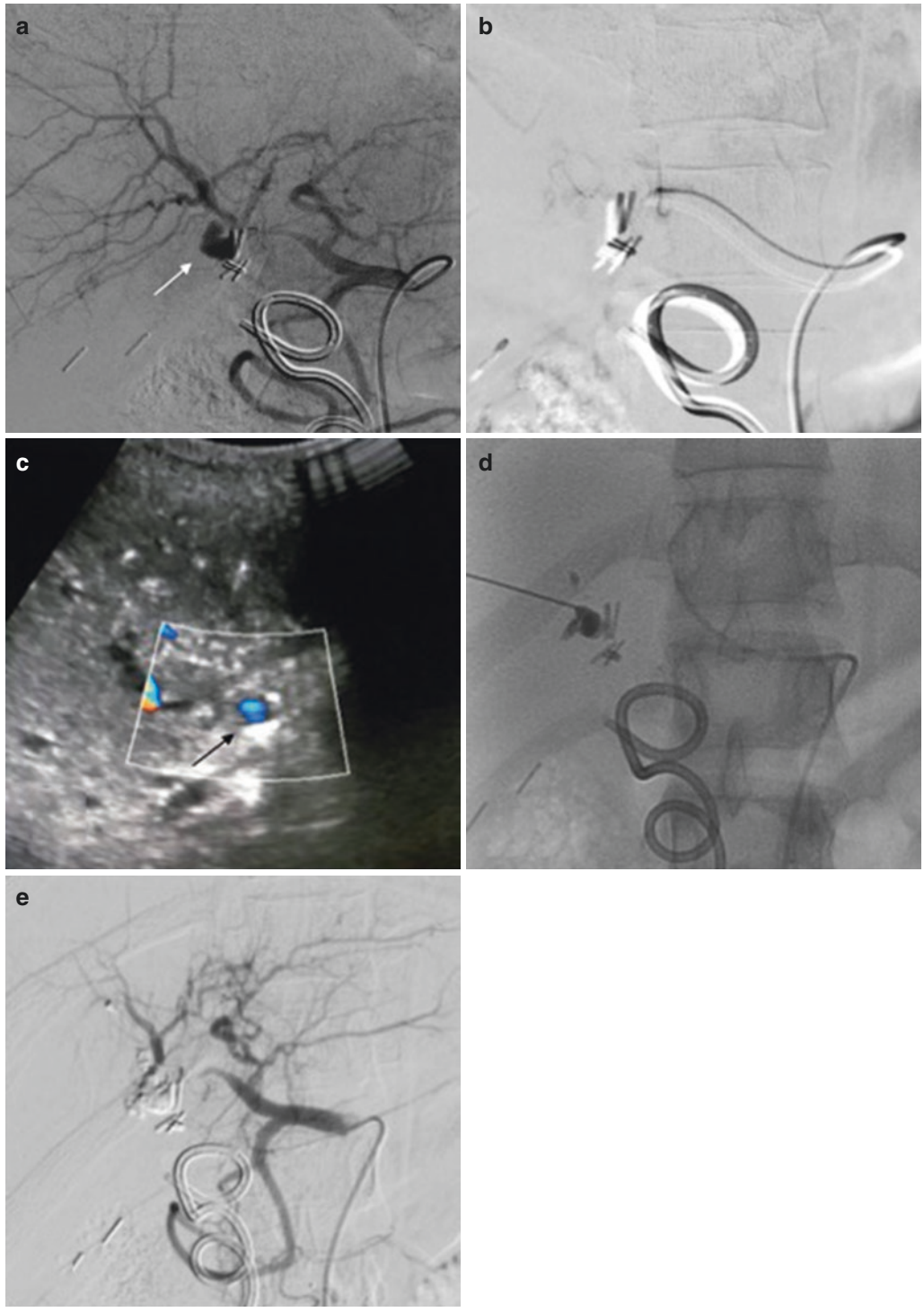


Fig. 7.4 Post-cholecystectomy day 17 with hemorrhagic output from drain. (**a**) Common hepatic artery angiogram showing attenuated right hepatic artery and pseudoaneurysm (arrow). (**b**) Guide wire could not be negotiated across the attenuated right hepatic artery. (**c**) Colour Doppler showing pseudoaneurysm (arrow). (**d**) 22G spinal needle in pseudoaneurysm with glue cast, placed under USG/fluoroscopy guidance. (**e**) Post-glue embolization angiogram of common hepatic artery shows obliteration of pseudoaneurysm

mild, may require occasional symptomatic treatment, and subside spontaneously in 2–5 days.

7.10 Complications and Their Management

Standard complications common to all angiography procedures can occur during endovascular/percutaneous management of hemobilia. Other than puncture-related complications, embolization procedure-related complications include pseudoaneurysm rupture, arterial dissection, and nontarget embolization leading to organ ischemia. Pseudoaneurysm rupture during endovascular embolization is dealt with immediate liquid embolic agents or gelfoam embolization. Ruptures during percutaneous embolization will need emergent endovascular or surgical management. Flow limiting arterial dissection involving a major artery is managed by balloon angioplasty/stent insertion. Nontarget embolization leading to ischemia is extremely rare due to the dual blood supply of the liver. However, it can be catastrophic in a patient who has portal vein thrombosis or in a transplant liver. Biliary strictures which are usually a delayed complication of hepatic artery embolization will require treatment with endoscopic and/or percutaneous techniques such as cholangioplasty and stenting [4].

7.11 Surgery

Surgical interventions are rarely needed in hemobilia cases when endovascular and percutaneous procedures fail to control hemorrhage. Surgery is however treatment of choice for pseudoaneurysms which are infected or which are compressing adjacent vital structures [10]. Surgical treatment options for hemobilia include hepatic artery ligation or excision of hepatic artery pseudoaneurysm. Hepatic segmentectomy or lobectomy is performed as last resort. Success rates of surgery are high (approximately 90%) however relatively high mortality (10%) may be encountered [4].

7.12 Bile Clearance

As already stated, clot formation within biliary tree can lead to jaundice, by obstructing bile flow with resultant acute cholangitis, acute cholecystitis, or acute pancreatitis [7, 9]. Timely drainage of bile is an important adjunct in managing patients of hemobilia.

Placement of a PTBD catheter with regular saline flush can be done to manage biliary obstruction due to thrombus. ERCP with sphincterotomy, nasobiliary drainage, and/ or biliary stenting can also be performed to relieve biliary obstruction [9].

7.13 Conclusion

Hemobilia is an uncommon but important cause of GI bleed. Clinical diagnosis can be challenging in patients without history of recent hepatobiliary interventions, trauma or malignancy. CT angiography and endoscopy are initial diagnostic modalities, choice of which depends on clinical probability of hemobila. Interventional radiologist plays central role in managing patients of hemobilia primarily via endovascular embolization. Vascular stenting however is invaluable in conditions where preservation of distal blood flow is paramount. Patients in whom endovascular therapies fail percutaneous thrombin or glue injection can be a reasonable alternative in certain situations. Surgery is reserved as a last resort and is rarely performed in patients of hemobilia due to its relatively higher complication rate and invasive nature.

References

1. Glisson F. Anatomia Hepatis. London: O. Pullein; 1654.
2. Sandblom P. Hemorrhage into the biliary tract following trauma; traumatic hemobilia. Surgery. 1948;24(3):571–86.
3. Quinke H. Ein Fall von Aneurysma der Leberarterie. Klin Wochenschr. 1871;88:773–86.
4. Murugesan SD, Sathyanesan J, Lakshmanan A, et al. Massive hemobilia: a diagnostic and therapeutic challenge. World J Surg. 2014;38(7):1755–62.

5. Green MH, Duell RM, Johnson CD, et al. Haemobilia. Br J Surg. 2001;88(6):773–86.
6. Berry R, Han J, Kardashian HA, et al. Hemobilia: etiology, diagnosis, and treatment. Liver Res. 2018 Dec;2(4):200–8.
7. Zhou H-B. Hemobilia and other complications caused by percutaneous ultrasound-guided liver biopsy. World J Gastroenterol. 2014;20(13):3712–5.
8. Rivera-Sanfeliz GM, Assar O, LaBerge JM, et al. Incidence of important hemobilia following transhepatic biliary drainage: left- sided versus right-sided approaches. Cardiovasc Intervent Radiol. 2004;27(2):137–9.
9. Navuluri R. Hemobilia. Semin Intervent Radiol. 2016;33(4):324–31.
10. Chin MW, Enns R. Hemobilia. Curr Gastroenterol Rep. 2010;12(2):121–9.
11. Vachhani PG, Copelan A, Remer EM, Kapoor B. Iatrogenic hepa- topancreaticobiliary injuries: a review. Semin Intervent Radiol. 2015;32(2):182–94.
12. Tessier DJ, Fowl RJ, Stone WM, et al. Iatrogenic hepatic artery pseudoaneurysms: an uncommon complication after hepatic, biliary, and pancreatic procedures. Ann Vasc Surg. 2003;17(6):663–9.
13. Goffette PP, Laterre PF. Traumatic injuries: imaging and interven- tion in post-traumatic complications (delayed intervention). Eur Radiol. 2002;12(5):994–1021.
14. Mutignani M, Shah SK, Bruni A, Perri V, Costamagna G. Endoscopic treatment of extrahepatic bile duct strictures in patients with portal biliopathy carries a high risk of haemobilia: report of 3 cases. Dig Liver Dis. 2002;34(8):587–91.
15. Bismuth H. Hemobilia. N Engl J Med. 1973;288(12):617–9.
16. Kandarpa K, Machan L, Durham JD. Handbook of interventional radiologic procedures. New York: Wolters Kluwer; 2016.
17. Srivastava DN, Sharma S, Pal S, et al. Transcatheter arterial embolization in the management of hemobilia. Abdom Imaging. 2006;31(4):439–48.
18. Cagli B, Tuncel SA, Sengul E, et al. Hemobilia and occult cystic artery stump bleeding after a laparoscopic cholecystectomy: endovascular treatment with N-butyl cyanoacrylate. Prague Med Rep. 2011;112(2):132–6.
19. Krokidis ME, Hatzidakis AA. Acute hemobilia after bilioplasty due to hepatic artery pseudoaneurysm: treatment with an ePTFE-covered stent. Cardiovasc Intervent Radiol. 2009;32(3):605–7.
20. Ruffino M, Rabbia C, Italian Cardiatis Registry Investiagtors Group. Endovascular treatment of visceral artery aneurysms with Cardiatis multilayer flow modulator: preliminary results at six-month follow-up. J Cardiovasc Surg. 2011;52:311–21.
21. Anton S, Stahlberg E, Horn M, Wiedner M, Kleemann M, Barkhausen J, et al. Initial experience with the E-ventus(R) stent-graft for endovascular treatment of visceral artery aneurysms. J Cardiovasc Surg. 2018;59(2):225–31.
22. Gorsi U, Chaluvashetty S, Kalra N, et al. Percutaneous glue embolization as a primary treatment for visceral pseudoa- neurysms. Minim Invasive Ther Allied Technol. 2019;23:1.
23. Prasad TV, Gupta AK, Garg P, Pal S, Gamanagatti S. Minimally invasive image-guided interventional management of Haemobilia. Trop Gastroenterol. 2015;36(3):179–84.

8 IR Management of Budd–Chiari Syndrome

Amar Mukund and Basavaraj Biradar

8.1 Introduction

Budd–Chiari syndrome (BCS) is characterized by obstruction of hepatic venous outflow in the absence of cardiac pathology. BCS is categorized as primary or secondary based on the etiology of obstruction of hepatic veins. Primary BCS results from primary venous disease like venous thrombosis/venous stenosis or venous membrane occluding the hepatic venous outflow [1, 2]. Secondary BCS results from extrinsic compression/invasion of hepatic venous outflow due to hepatic/parasitic cyst, abscess, or any tumor [1]. BCS may have a varied presentation. It may be asymptomatic or may present as fulminant/acute/subacute and chronic forms, with subacute/chronic form being the most common presentation. Primary causes include congenital webs, inherited or acquired hypercoagulable and prothrombotic states which result in vascular stasis, thrombosis, eventually web/membrane formation, and obliterative venopathy [1, 2]. Secondary causes include extrinsic compression or tumor invasion of hepatic veins and/or inferior vena cava (IVC). Obstruction to venous outflow along the drainage pathway can occur at various sites right from hepatic venules to IVC entry into the right atrium [3].

Acute BCS results due to sudden thrombosis of hepatic vein (HV) and/or intrahepatic IVC and manifests as abdominal pain, jaundice, and distension, secondary to hepatomegaly, and/or ascites [1–4]. Histologically, acute form is characterized by hepatic sinusoidal congestion, dilatation, and hepatocyte necrosis [3–5]. Chronic BCS is usually insidious in onset and presents with impaired liver biochemical parameters and signs of portal hypertension or complications such as bleeding varices. Histologically, it is characterized by centrilobular fibrosis with atrophy of involved segments and compensatory hypertrophy of spared segments in the background of chronic liver disease [3–5]. Formation of multiple intrahepatic veno-venous collaterals, regenerative nodules, and ultimately cirrhosis is seen in chronic form [3–5]. Both acute and chronic forms result in reduced hepatic perfusion and eventually rise in portal pressure leading to portal hypertension [4]. Imaging by various modalities like ultrasound, CT/MRI usually confirms diagnosis without the need for biopsy (Figs. 8.1 and 8.2). Biopsy is advised only when the diagnosis is uncertain or if obstruction to outflow at the level of small intrahepatic veins is suspected [5].

Anticoagulation and beta-blocker therapy form initial management strategy but do not address underlying outflow obstruction pathology. Surgical shunts are more invasive in nature and have high risk of shunt thrombosis, perioperative morbidity, and mortality in decompen-

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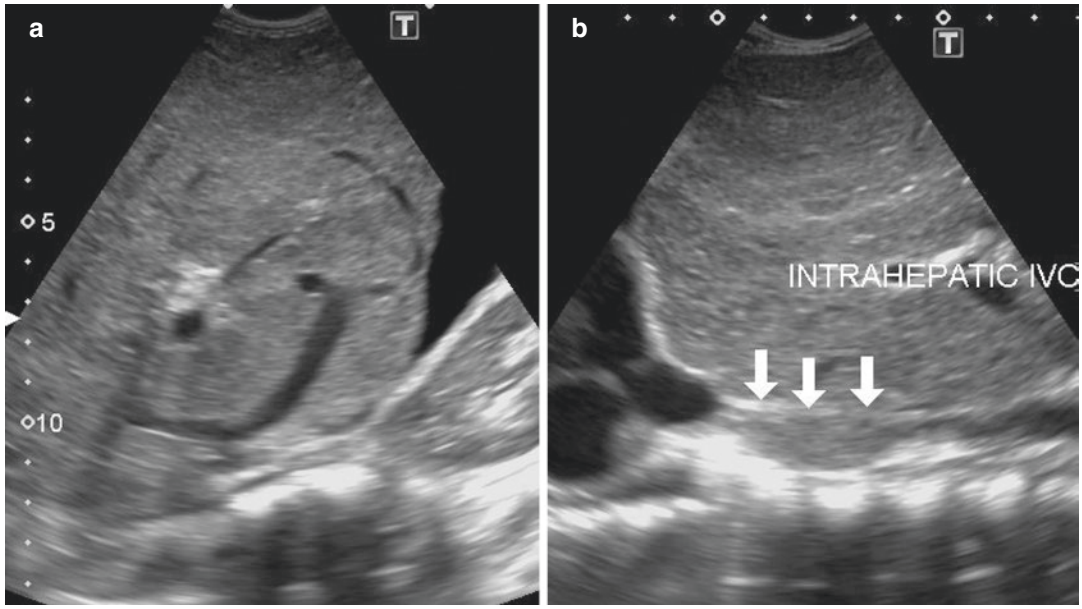

Fig. 8.1 US image (**a**) shows intrahepatic veno-venous, comma-shaped bridging venous collaterals, (**b**) shows long segment occlusion of IVC

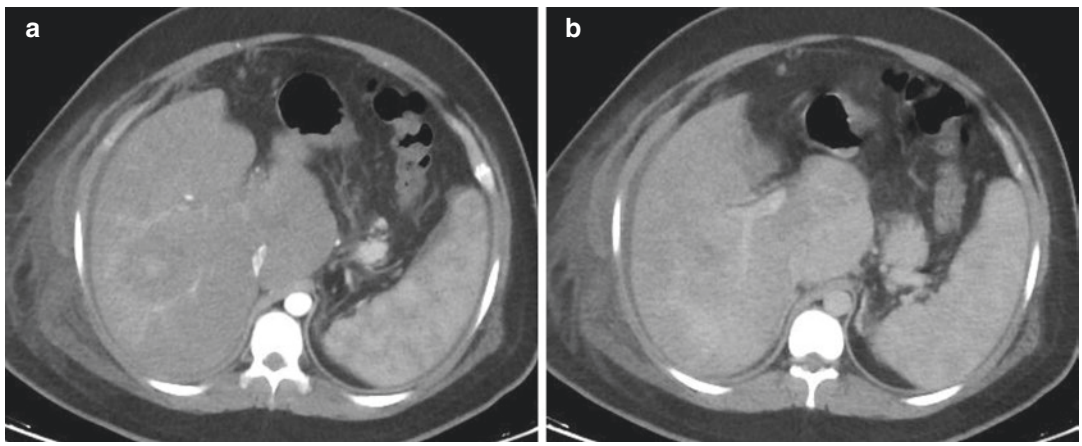

Fig. 8.2 Axial CECT shows heterogeneous enhancement with caudate lobe enlargement in arterial phase (**a**) and venous phase (**b**) images

sated patients [6, 7]. Liver transplantation although has shown excellent results but availability of organ, risks of long-term immunosuppression, expertise, and cost factor have been the limiting factors particularly in developing countries [8].

Interventional radiology has emerged as a promising, minimally invasive, and effective treatment in managing BCS patients. Various image-guided interventions such as percutaneous angioplasty with thrombolytic therapy, stenting, creation of transjugular intrahepatic portosystemic, or direct intrahepatic portocaval shunt creation are described which have prolonged 5-year survival to about 75% in patients having BCS [9]. Endovascular treatment has been very effective in relieving hepatic congestion and symptoms of portal hypertension. These treatments are aimed at restoring the venous out-

flow or creating a portosystemic shunt leading to the improvement in the liver functions and providing long-term transplant free survival. Factors determining IR approach for the management of BCS include presentation of disease (acute or chronic), length of occlusion of HV/IVC, caliber of diseased HV, status of IVC (length of occlusion/presence of thrombus), status of portal vein (patent/thrombosed/cavernomatous), and presence of accessory inferior hepatic vein. Therapeutic stepwise approach to BCS begins from anticoagulation, diuretics, medical management of portal hypertension, angioplasty with or without stenting for venous stenosis, creation of portosystemic shunts and ultimately liver transplantation. Addressing underlying hematological cause supplementing radiological intervention is crucial as restenosis or treatment failure is common in its absence. An algorithmic approach for managing BCS patients is presented in Fig. 8.3.

8.2 Acute BCS

8.2.1 Thrombolysis

The use of local as well as systemic thrombolytic therapy has been described for acute and subacute disease having hepatic venous IVC thrombosis in the absence of membranous obstruction/stenosis. Local thrombolysis is done by accessing the thrombosed hepatic vein through the jugular access and initiating an intra-clot catheter-directed thrombolysis. Additional mechanical thrombolysis can be performed depending upon the age of the thrombus. Pharmacological thrombolysis using tPA (5 mg bolus followed by 0.5 mg/hour for six hours) or urokinase (3000 units/kg bolus followed by 50,000 units/hr. for 6–12 h) is preferred in hyperacute stage, whereas older thrombus may require

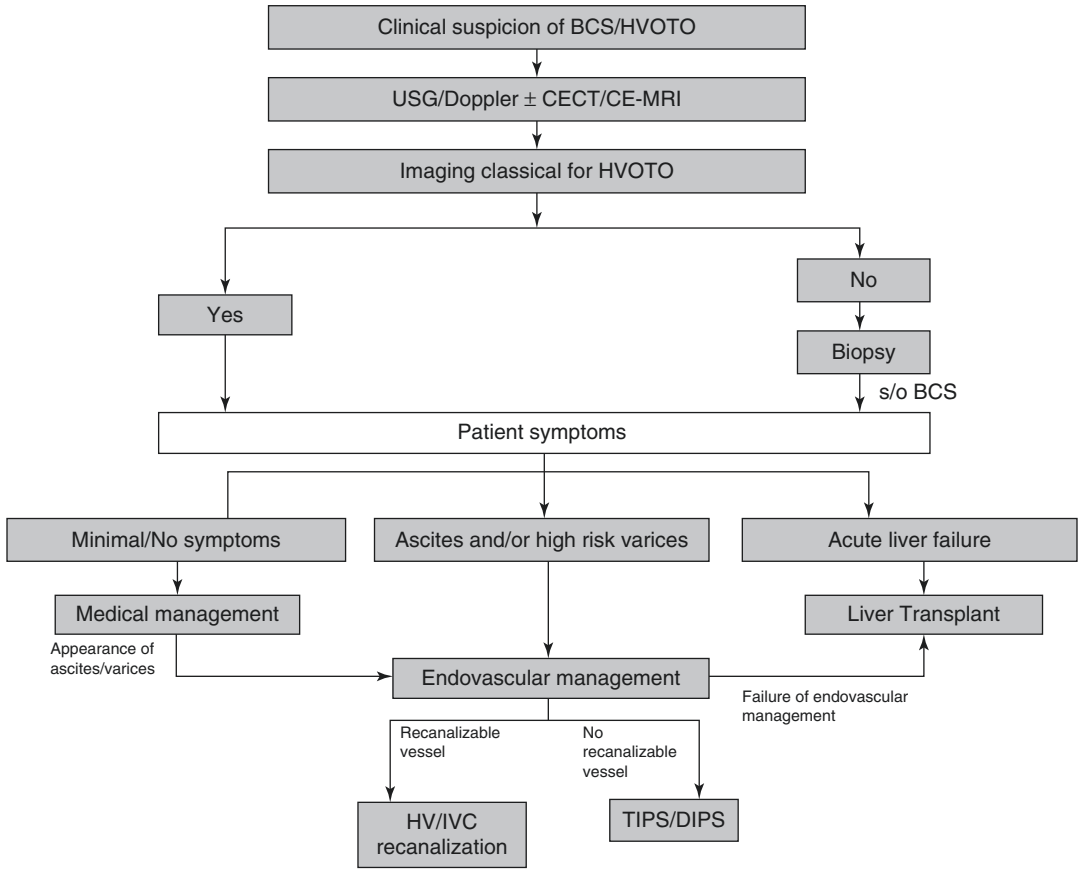

Fig. 8.3 Proposed algorithm for the management of BCS patients

additional mechanical thrombolysis [10, 11]. Thrombolysis is best suited for thrombus not older than 3–4 weeks. Stent placement in the HV should be avoided in acute disease and should be used only in cases with ostial stenosis of HV. Few studies have described the direct infusion of thrombolytic drugs into the hepatic artery to achieve high concentration in hepatic veins but no significant benefit was achieved [11, 12].

8.3 Subacute/Chronic BCS

8.3.1 Angioplasty of IVC and/or Hepatic Vein

Ideal treatment for symptomatic patients with short segment stenosis or membranous obstruction of hepatic veins or IVC consists of recanalizing these occluded segments by endovascular techniques and angioplasty of the stenosed venous segment [13].

Short segment/membranous occlusion of suprahepatic IVC is one of the commonest causes of BCS in Asia. IVC occlusions may be approached by femoral or jugular venous access and recanalization with dilatation of the occluded/stenosed segment may be performed (Figs. 8.4 and 8.5). Crossing a tight stricture may be difficult and may require additional maneuver like coaxial placement of long sheath with its tip reaching the occluded segment along with the guiding catheter and a straight tip guidewire being used to cross the stricture. If the stricture is too tight then a combined jugular and femoral approach may be employed with long sheaths placed up to the stricture from both the access and probing the stricture from both sides. If all maneuver fails then a balloon may be inflated just below the occlusion and it may be targeted from the opposite end of stenosis/membrane (after confirming the hardware on either side of stricture are in straight line by obtaining views in orthogonal plane, both antero-posterior and lateral view) using a long chiba needle/colapinto needle. Use of needle to cross the stricture should be done with a great caution as a wrong puncture may have a catastrophic sequel. Once the stenotic segment is crossed then serial dilatation is performed, initially by smaller diameter balloon catheter followed by a larger balloon catheter [1]. Post- angioplasty establishment of a good forward flow with the disappearance of collateral filling indicates a good technical success (Fig. 8.5). The procedure is termed clinically successful if there is alleviation of symptoms with improvement in liver function tests.

In cases with hepatic venous obstruction, identifying the suitable hepatic vein for recanalization is of utmost importance to achieve a long-term patency after the intervention. The hepatic vein being considered for recanalization should

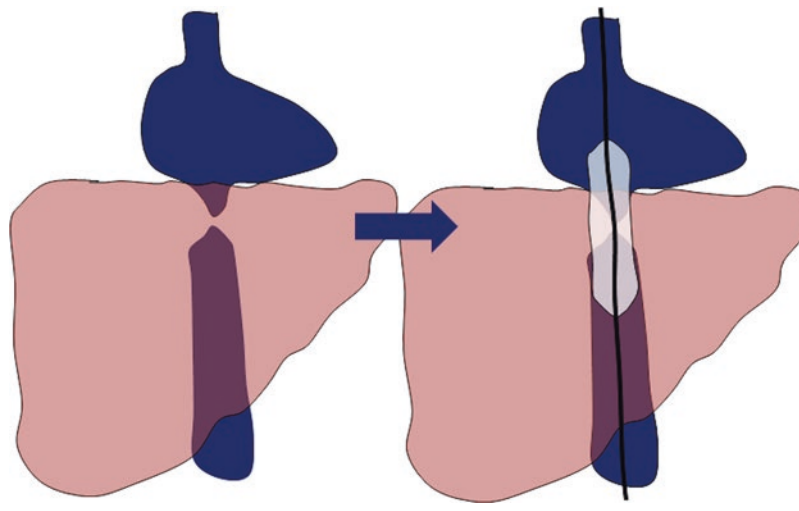

Fig. 8.4 Schematic diagram showing BCS with short segment occlusion of IVC which can be treated by crossing the stricture and balloon dilatation of the strictured segment with or without stent placement

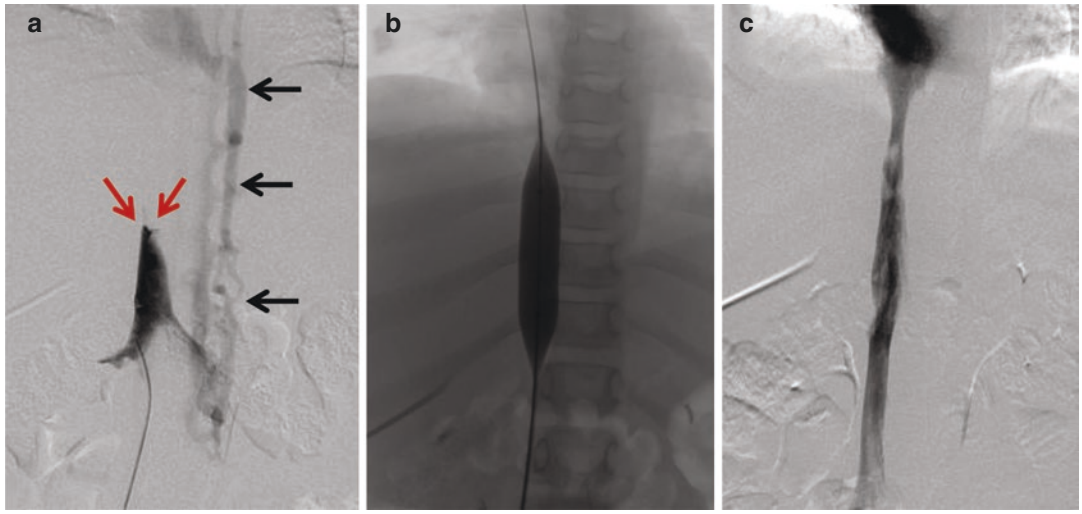

Fig. 8.5 DSA image (**a**) shows IVC gram being performed through femoral access with long segment occlusion of the intrahepatic IVC (red arrows) with enlarged azygous venous system (black arrows) as an alternate venous drainage pathway. Fluoroscopic image (**b**) shows balloon angioplasty being performed and (**c**) shows post venoplasty IVC gram showing good flow of contrast in the previously occluded IVC

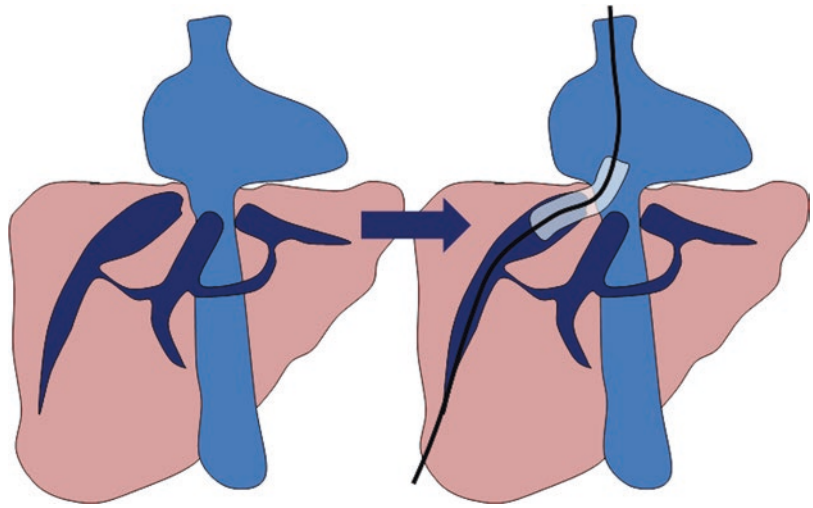

Fig. 8.6 Schematic diagram showing BCS with short segment occlusion of HV and patent IVC. Such occlusions can be treated by balloon dilatation of the strictured segment with or without stent placement

be a native hepatic vein, straight in course, echo-free lumen on ultrasound with a caliber of atleast 7–8 mm in adults. It should be draining sizable hepatic parenchyma with evidence of veno-venous collaterals joining this vein (Fig. 8.6).

The target hepatic vein is approached through transjugular access using an angled catheter and guide wire with or without long sheath and/or angled metallic cannula (RUPS set, Cook, Bloomington, Indiana). After successful negotiation of the guide wire across the stenosis, the catheter is advanced over it and the floppy guide wire is replaced by a stiff guide wire and serial angioplasty of the stenosed segment is performed using high pressure noncompliant balloon. After performing the angioplasty, venogram is performed and the pressure gradient across the recanalized segment is measured.

If cannulation of hepatic vein fails through transjugular approach, percutaneous transhepatic route can be used to directly puncture the occluded hepatic vein under ultrasound guidance (Fig. 8.5). A 21/22 g needle is used to access the HV, which is replaced by a 5f vascular sheath. A 5f KMP catheter (Cook, IN) with floppy J/straight tip guide wire is used to cross the stenosis and enter the IVC. In case of tight stricture, reverse end of the guide wire may be used to cross the stricture. After crossing the stricture the catheter is advanced and a J tip floppy guide wire is used to navigate into the superior vena cava or sometimes into the IVC. The tip of the guide wire is then snared out through the jugular or femoral access (Fig. 8.5). After the wire tip is snared out, angioplasty and/or stenting is performed through the jugular/femoral access. A good forward flow with the disappearance of collateral veins is suggestive of technical success (Fig. 8.7).

Angioplasty for the stenosed segment of the hepatic vein may be performed by percutaneous transhepatic access as well; however, it needs placement of large diameter vascular sheath which may have an increasing the risk of hemoperitoneum. Embolizing the percutaneous tract with coils and gelfoam can minimize the chances of hemoperitoneum after removal of the vascular sheath [14]. Monitoring of patient's vitals is important to prevent and mange any post-procedure complications.

8.3.2 Complications

The incidence of complications for angioplasty is negligible (<5%). Few technical major complications such as hepatic capsule perforation, IVC rupture, cardiac injury, hepatic artery injury, hemoperitoneum is mainly caused by inadequate experience [9].

8.3.3 HV/IVC Stenting

Post-angioplasty status of occluded hepatic vein segment and suprahepatic IVC determines stent placement strategy. Persistence of significant residual stenosis (>30%) or pressure difference of >5 mm Hg post-angioplasty suggests that stent is required to maintain the patency [15, 16].

Although few studies have advocated combined metallic stenting with angioplasty to avoid restenosis and reduce secondary complications [17]. However, it is still unclear about the benefits of stenting combined with angioplasty v/s angioplasty alone at the first session.

8.3.4 TIPS/DIPS

BCS patients with no recanalizable hepatic vein due to complete/long segment occlusions with tiny venous collaterals need creation of portosystemic shunts for providing venous outflow and hence decompressing the congested liver (Fig. 8.8). The indications for TIPS/DIPS include

- Absence of any recanalizable hepatic vein.
- Those who do not to respond to anticoagulation therapy and angioplasty.
- Failure of recanalization procedure.
- Disease progression despite successful hepatic vein angioplasty and/or stenting.

Contraindications:

- Severe hepatic dysfunction.
- Polycystic liver disease.
- Chronic complete portal vein thrombosis with the formation of cavernoma.

BCS-TIPS Prognostic index (age, bilirubin, and INR) score of >7 indicates extremely ill patients and hence this group of patients are candidates for early liver transplantation [7].

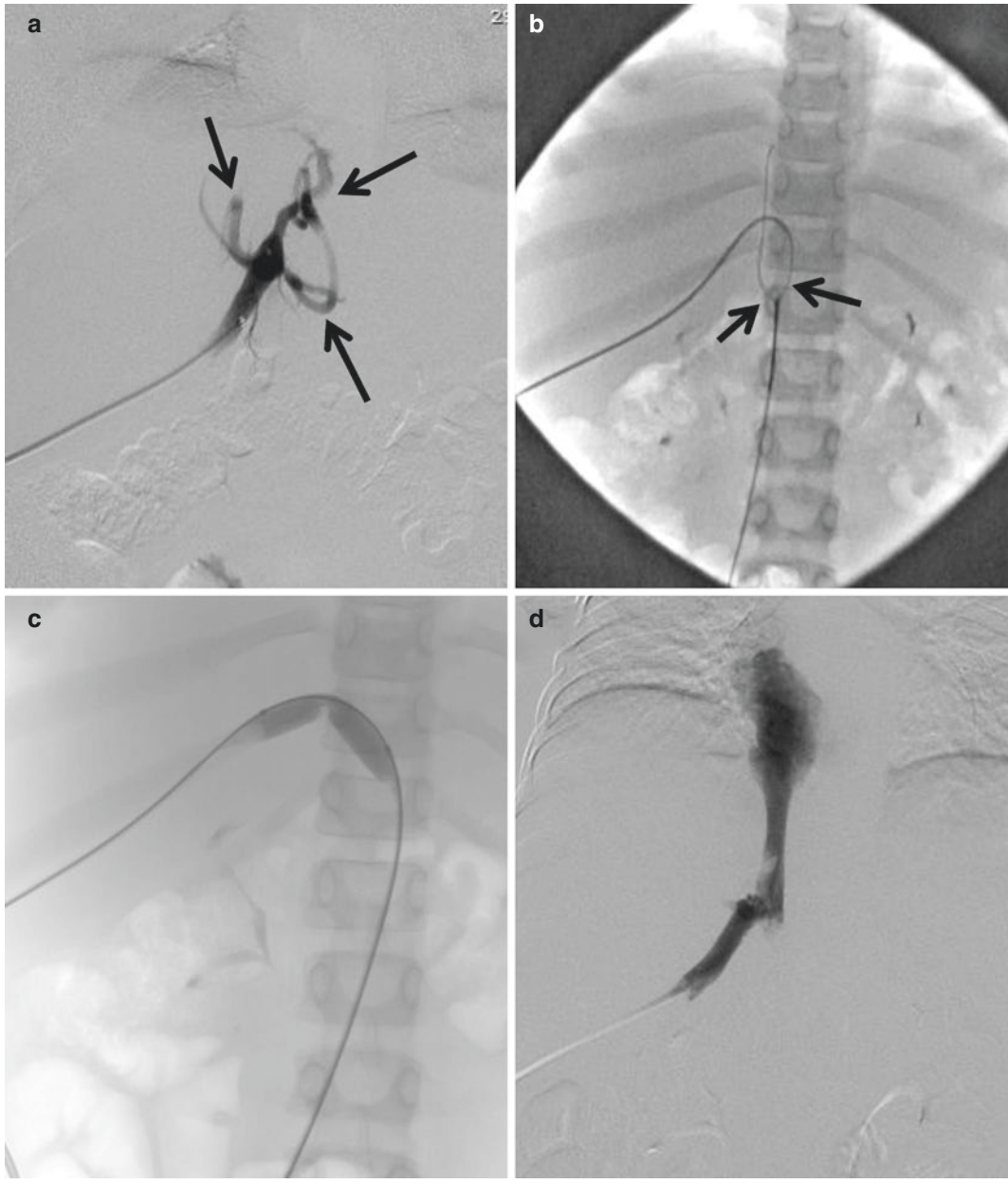

Fig. 8.7 DSA image (**a**) shows percutaneous hepatic venogram with short segment occlusion of right accessory hepatic vein at HV/IVC junction with small veno-venous channels (black arrows), fluoroscopic image (**b**) shows guidewire being snared out after negotiation it across the stricture (black arrows) and (**c**) shows venoplasty being performed. DSA image (**d**) shows resolution of stricture with good flow of contrast across the previously strictured segment of right accessory hepatic vein

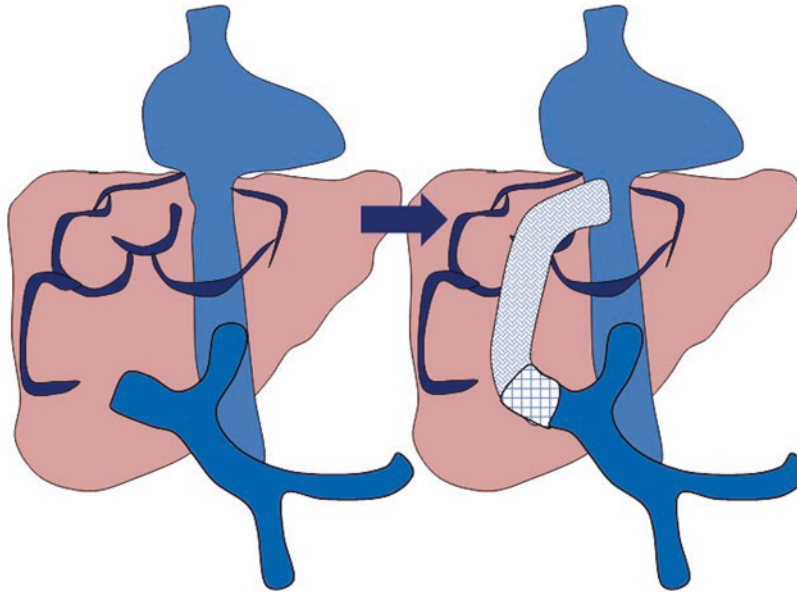

Fig. 8.8 Schematic diagram showing BCS with thrombosed/fibrosed native HV, replaced by multiple tiny collateral channels. This group of patients can be treated by creating a DIPS across IVC and portal vein

8.3.5 TIPS/DIPS Technique

Right internal jugular venous access is obtained and the guidewire is advanced in the IVC. Thereafter, a long sheath is placed in the intrahepatic IVC. The metallic cannula available with the RUPS TIPS set (Cook, Bloomington, IN) is used to wedge at the level of hepatic vein ostium. The sheath and cannula assembly is wedged and kept stable at the junction of supra-intrahepatic IVC. A catheter mounted puncture needle or a long Chiba needle is used to enter the liver parenchyma and the metallic cannula is slightly advanced over it. Later the metallic cannula is steered to direct the puncture needle/Chiba needle toward the right portal vein (simultaneous use of transabdominal/intravascular ultrasound may help in accurate positioning of the needle while trying to puncture the portal vein). After the successful portal vein puncture (Fig. 8.9) the guidewire is advanced into the splenic vein/superior mesenteric vein and later exchanged for a stiff guidewire. The parenchymal track is dilated over the stiff guide wire using balloon catheter and size of DIPS stent to be placed is ascertained on venogram obtained using sizing pigtail catheter (Fig. 8.9). After determining the length of the stent, a DIPS stent is deployed from IVC to the portal vein with covered part of stent position from IVC upto the point of portal puncture while a small uncover stent is extended by about 2 cm into the portal vein branch toward the main portal vein (Fig. 8.6). After the DIPS procedure the patients are advised to maintain INR of 2–3 [18].

8.3.6 Complications

Complications are usually procedure related and consist of hemoperitoneum (secondary to hepatic capsule puncture by needle while attempting a portal vein puncture or extrahepatic puncture of the portal vein) hemobilia due to injury to bile duct, heart failure, access site infection or jugular vein thrombosis, supraventricular tachycardia, portal vein dissection and thrombosis, stent migration. Delayed complications consist of stent occlusion, IVC obstruction by stent and hemolysis, hepatic encephalopathy.

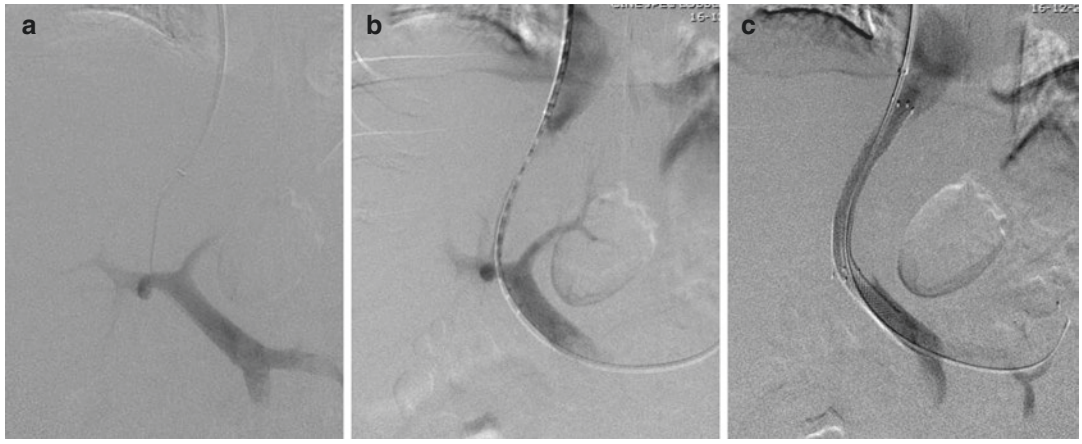

Fig. 8.9 DSA images showing DIPS being performed, (**a**) shows portal venogram after portal puncture and placement of angiographic catheter in portal vein, (**b**) shows simultaneous IVC and portal venogram with calibration pigtail catheter to ascertain the size of the DIPS stent to be placed, (**c**) shows DIPS venogram being performed after placement of DIPS stent

Outcomes of BCS Radiological Interventions (Hepatic/IVC Angioplasty and Stenting) in Regards to Patency, Survival, Clinical Symptom Resolution, Safety, and Technical Efficacy

Han G et al. [17] showed good long-term patency and survival in BCS patients who underwent percutaneous recanalization ± stenting. The technical efficacy was 95% with primary patency rates of 95%, 77%, and 58% at 1, 5, and 10 years, respectively. The overall survival rates at 1, 5, and 10 years were 96%, 83%, and 73%, respectively.

In a study by Li T et al. [19] in 101 BCS patients treated with percutaneous balloon angioplasty ± stenting, 92 patients showed prompt symptom resolution. Technical efficacy was 91% with no perioperative mortality. The primary patency rates at 6, 12, and 24 months were 84%, 78%, and 76%, respectively. The secondary patency rates at 6, 12, and 24 months were 95%, 92%, and 84%, respectively.

Retrospective analysis of 92 BCS patients who underwent percutaneous anatomic recanalization ± stenting the author himself [20], showed a good midterm outcomes and transplant-free survival rate in patients undergoing recanalization of HV/IVC. Complete resolution of symptoms was seen in 94.5% of patients within 4–6 weeks post-intervention. During follow-up, four patients showed stent dysfunction with symptom recurrence. Stent recanalization was done in all these patients who showed immediate clinical symptom relief with good secondary patency rates and transplant-free survival period.

Retrospective analysis of 63 patients of BCS treated with radiological interventions by Eapen CE et al. [21] showed good midterm survival. Survival analysis of patients based on severity of disease(Murad classification) was assessed. Survival rates at 1 and 5 years were 100% in mild disease, 94% and 86% in intermediate disease, 85%, and 77% in severe disease, respectively.

Tripathi D et al. [22] showed good outcomes In BCS patients in terms of patency and survival when venoplasty is combined stenting. Technically efficacy was 100% in their study with prompt symptom resolution in 73% of patients. Secondary patency rates at 1, 5, and 10 years were 92%, 79%, and 79%, respectively, and overall survival rates at 1,5,10 years were 97%, 89%, and 85%, respectively.

Zhang CQ et al. [23] evaluated the long-term effect of hepatic vein and IVC stenting in 115 BCS patients with short segment obstruction. Thirty patients had hepatic vein stenting, 102

patients had IVC stenting and 17 patients had both IVC and hepatic vein stenting. Technical success was 94% and 87% in IVC and hepatic vein stenting respectively. Excellent long-term patency rates were achieved.

The role and advantages for TIPS over surgical portosystemic shunts in BCS have been validated by several studies in the literature [7, 24, 25].

Few studies have compared pre-emptive TIPS (without prior angioplasty) v/s converted TIPS (post failed angioplasty) but found no significant difference in survival [26–28]. However, no sufficient data exists in favor of TIPS replacing angioplasty as a first line of interventional treatment in all BCS patients. Factors like risk of HE and more invasiveness with TIPS also limit TIPS for the considering as first line of treatment.

8.4 Bleeding Risk in IR Procedures for BCS Patients

Intervention in BCS patients is technically challenging. Also, as all patients of BCS require anticoagulation pre- and post-intervention to maintain patency of treated vessel or stented segment, this poses increased risk of bleeding perioperatively. Rautou PE et al. reported 27% of patients in their study showed major risk of bleeding episodes post-percutaneous intervention [29]. This warrants close monitoring of patients in postoperative period for any bleeding events such as hemoperitoneum, hemobilia, and subcapsular hematoma. Early treatment with short-acting anticoagulants and shifted to warfarin with titrated dose monitoring INR is advised [30].

Currently Available Prognostic Indices (PI) Predicting Treatment Efficacy Are

(a) BCS-TIPS PI.
(b) Child-Pugh score.
(c) Model for end-stage liver disease (MELD).
(d) Clichy PI.
(e) Rotterdam PI.
(f) albumin-bilirubin (ALBI) score,
(g) CLIF Consortium acute decompensation (CLIF-C AD) score.

Variables needed to calculate abovementioned scores include—age, WBC, hepatic encephalopathy, ascites, serum creatinine, serum albumin, serum bilirubin, and INR.

8.5 Poor Prognosis for Intervention

The cutoff value indicating poor prognosis for interventions in patients with BCS are as follows: BCS-TIPS PI >7, Rotterdam BCS score—class III/> 1.5 points, Clichy score > 6.6, MELD >20 points, and CTP score > 10 points /class C. The role of Rotterdam score in predicting intervention-free survival and BCS-TIPS PI in predicting survival has been validated in a study by Susan seijo et al. [31].

8.6 Follow-Up

Follow-up after intervention (hepatic vein angioplasty/stenting and DIPS/TIPS) should be scheduled at 1 month, 3 months, and thereafter every 6 months. At follow-up, clinical and ultrasonography evaluation of recanalized vein or shunt is performed looking for the patency of the vein/shunt with any sign of dysfunction [32]. In equivocal result on ultrasound, a contrast CT or venogram of the vein/shunt may be performed to confirm the patency. Restenosis due to intimal hyperplasia or thrombus formation is addressed by repeat balloon dilatation or re-stenting. Transient elastography has been used to measure liver stiffness also aids in assessing treatment response. Liver stiffness values pre- and post-intervention allow assessment of hepatic congestion changes and transplant-free survival period [33]. In addition to it, liver stiffness measurements (LSM) provide good insight in follow-up of asymptomatic patients as when to offer endovascular treatment. Persistent rising values of LSM values in asymptomatic patients is an indication for further intervention [34].

8.7 Future Perspective

Studies have shown successful TIPS shunt creation in patients with portal vein thrombus via trans-splenic access [35, 36]. This can be employed in BCS cases presenting simultaneously with portal vein thrombus or occlusion. Trans-splenic access can be considered for TIPS shunt formation in patients with preserved liver synthetic functions. Improved patency of recanalized hepatic veins and TIPS stent due to advancement in stent and balloon technology may improve long-term outcomes and transplant-free survival period.

8.8 Conclusion

The primary goal of radiological intervention in BCS is to relieve sinusoidal congestion by re-establishing hepatic venous outflow, improve liver function, reduce portal hypertension and its complications. Stepwise approach should be the guide to interventional radiologist beginning from anticoagulation, angioplasty to portosystemic shunt (TIPS/DIPS) depending on feasibility based on imaging. Due to favorable mid and long-term outcomes, minimal invasiveness and good 5-year transplant-free survival period, radiological interventions have replaced surgery as first line of management of BCS patients. However, BCS patients with fulminant disease/acute liver failure are best suited for liver transplantation.

References

1. Mukund A, Gamanagatti S, Acharya SK. Radiological interventions in HVOTO--practical tips. Trop Gastroenterol. 2011 Jan-Mar;32(1):4–14.
2. Okuda K. Inferior vena cava thrombosis at its hepatic portion (obliterative hepatocavopathy). Semin Liver Dis. 2002 Feb;22(1):15–26.
3. Valla DC. The diagnosis and management of the Budd-Chiari syndrome: consensus and controversies. Hepatology. 2003 Oct;38(4):793–803.
4. Valla D, Benhamou JP. Obstruction of the hepatic veins or suprahepatic inferior vena cava. Dig Dis. 1996 Mar-Apr;14(2):99–118.
5. Van Wettere M, Bruno O, Rautou PE, Vilgrain V, Ronot M. Diagnosis of Budd-Chiari syndrome. Abdom Radiol (NY). 2018 Aug;43(8):1896–907. https://doi.org/10.1007/s00261-017-1447-2.
6. Zeitoun G, Escolano S, Hadengue A, Azar N, El Younsi M, Mallet A, Boudet MJ, Hay JM, Erlinger S, Benhamou JP, Belghiti J, Valla D. Outcome of Budd-Chiari syndrome: a multivariate analysis of factors related to survival including surgical portosystemic shunting. Hepatology. 1999 Jul;30(1):84–9.
7. Garcia-Pagán JC, Heydtmann M, Raffa S, Plessier A, Murad S, Fabris F, Vizzini G, Gonzales Abraldes J, Olliff S, Nicolini A, Luca A, Primignani M, Janssen HL, Valla D, Elias E, Bosch J, Budd-Chiari Syndrome-Transjugular Intrahepatic Portosystemic Shunt Group. TIPS for Budd-Chiari syndrome: long-term results and prognostics factors in 124 patients. Gastroenterology. 2008 Sep;135(3):808–15. https://doi.org/10.1053/j.gastro.2008.05.051.
8. Darwish Murad S, Kamath PS. Liver transplantation for Budd-Chiari syndrome: when is it really necessary? Liver Transpl. 2008 Feb;14(2):133–5. https://doi.org/10.1002/lt.21286.
9. Wang Q, Han G. Image-guided treatment of Budd-Chiari syndrome: a giant leap from the past, a small step towards the future. Abdom Radiol (NY). 2018 Aug;43(8):1908–19. https://doi.org/10.1007/s00261-017-1341-y.
10. Hauser AC, Brichta A, Pabinger-Fasching I, Jäger U. Fibrinolytic therapy with rt-PA in a patient with paroxysmal nocturnal hemoglobinuria and Budd-Chiari syndrome. Ann Hematol. 2003 May;82(5):299–302.
11. Sharma S, Texeira A, Texeira P, Elias E, Wilde J, Olliff SP. Pharmacological thrombolysis in Budd Chiari syndrome: a single centre experience and review of the literature. J Hepatol. 2004 Jan;40(1):172–80.
12. DeLeve LD, Valla DC, Garcia-Tsao G. American Association for the Study Liver Diseases: vascular disorders of the liver. Hepatology. 2009 May;49(5):1729–64. https://doi.org/10.1002/hep.22772.
13. Martin LG, Henderson JM, Millikan WJ Jr, Casarella WJ, Kaufman SL. Angioplasty for long-term treatment of patients with Budd-Chiari syndrome. AJR Am J Roentgenol. 1990 May;154(5):1007–10.
14. Mukund A, Gamanagatti S. Imaging and interventions in Budd-Chiari syndrome. World J Radiol. 2011 Jul 28;3(7):169–77. https://doi.org/10.4329/wjr.v3.i7.169.
15. Witte AM, Kool LJ, Veenendaal R, Lamers CB, van Hoek B. Hepatic vein stenting for Budd-Chiari syndrome. Am J Gastroenterol. 1997 Mar;92(3):498–501.
16. Pelage JP, Denys A, Valla D, Sibert A, Sauvanet A, Belghiti J, Menu Y. Budd-Chiari syndrome due to prothrombotic disorder: mid-term patency and efficacy of endovascular stents. Eur Radiol. 2003 Feb;13(2):286–93.
17. Han G, Qi X, Zhang W, He C, Yin Z, Wang J, Xia J, Xu K, Guo W, Niu J, Wu K, Fan D. Percutaneous recanalization for Budd-Chiari syndrome: an 11-year

retrospective study on patency and survival in 177 Chinese patients from a single center. Radiology. 2013 Feb;266(2):657–67. https://doi.org/10.1148/radiol.12120856.
18. de Franchis R. Evolving consensus in portal hypertension. Report of the Baveno IV consensus workshop on methodology of diagnosis and therapy in portal hypertension. J Hepatol. 2005 Jul;43(1):167–76.
19. Li T, Zhai S, Pang Z, Ma X, Cao H, Bai W, Wang Z, Zhang WW. Feasibility and midterm outcomes of percutaneous transhepatic balloon angioplasty for symptomatic Budd-Chiari syndrome secondary to hepatic venous obstruction. J Vasc Surg. 2009 Nov;50(5):1079–84. https://doi.org/10.1016/j.jvs.2009.06.049.
20. Mukund A, Mittal K, Mondal A, Sarin SK. Anatomic recanalization of hepatic vein and inferior vena cava versus direct intrahepatic portosystemic shunt creation in Budd-Chiari syndrome: overall outcome and midterm transplant-free survival. J Vasc Interv Radiol. 2018 Jun;29(6):790–9. https://doi.org/10.1016/j.jvir.2018.01.781.
21. Eapen CE, Velissaris D, Heydtmann M, Gunson B, Olliff S, Elias E. Favourable medium term outcome following hepatic vein recanalisation and/or transjugular intrahepatic portosystemic shunt for Budd Chiari syndrome. Gut. 2006 Jun;55(6):878–84.
22. Tripathi D, Sunderraj L, Vemala V, Mehrzad H, Zia Z, Mangat K, West R, Chen F, Elias E, Olliff SP. Long-term outcomes following percutaneous hepatic vein recanalization for Budd-Chiari syndrome. Liver Int. 2017 Jan;37(1):111–20. https://doi.org/10.1111/liv.13180.
23. Zhang CQ, Fu LN, Xu L, Zhang GQ, Jia T, Liu JY, Qin CY, Zhu JR. Long-term effect of stent placement in 115 patients with Budd-Chiari syndrome. World J Gastroenterol. 2003 Nov;9(11):2587–91.
24. Qi X, Guo W, He C, Zhang W, Wu F, Yin Z, Bai M, Niu J, Yang Z, Fan D, Han G. Transjugular intrahepatic portosystemic shunt for Budd-Chiari syndrome: techniques, indications and results on 51 Chinese patients from a single centre. Liver Int. 2014 Sep;34(8):1164–75. https://doi.org/10.1111/liv.12355.
25. Khuroo MS, Al-Suhabani H, Al-Sebayel M, Al Ashgar H, Dahab S, Khan MQ, Khalaf HA. Budd-Chiari syndrome: long-term effect on outcome with transjugular intrahepatic portosystemic shunt. J Gastroenterol Hepatol. 2005 Oct;20(10):1494–502.
26. Blokzijl H, de Knegt RJ. Long-term effect of treatment of acute Budd-Chiari syndrome with a transjugular intrahepatic portosytemic shunt. Hepatology. 2002 Jun;35(6):1551–2.
27. Mancuso A. Budd-chiari syndrome management: timing of treatment is an open issue. Hepatology. 2014 Mar;59(3):1213. https://doi.org/10.1002/hep.26619.
28. Rosenqvist K, Sheikhi R, Eriksson LG, Rajani R, Rorsman F, Sangfelt P, Nyman R. Endovascular treatment of symptomatic Budd-Chiari syndrome – in favour of early transjugular intrahepatic portosystemic shunt. Eur J Gastroenterol Hepatol. 2016 Jun;28(6):656–60. https://doi.org/10.1097/MEG.0000000000000621.
29. Rautou PE, Douarin L, Denninger MH, Escolano S, Lebrec D, Moreau R, Vidaud M, Itzykson R, Moucari R, Bezeaud A, Valla D, Plessier A. Bleeding in patients with Budd-Chiari syndrome. J Hepatol. 2011 Jan;54(1):56–63. https://doi.org/10.1016/j.jhep.2010.06.019.
30. European Association for the Study of the Liver. EASL clinical practice guidelines: vascular diseases of the liver. J Hepatol. 2016 Jan;64(1):179–202. https://doi.org/10.1016/j.jhep.2015.07.040.
31. Seijo S, Plessier A, Hoekstra J, Dell'era A, Mandair D, Rifai K, Trebicka J, Morard I, Lasser L, Abraldes JG, Darwish Murad S, Heller J, Hadengue A, Primignani M, Elias E, Janssen HL, Valla DC, Garcia-Pagan JC, European Network for Vascular Disorders of the Liver. Good long-term outcome of Budd-Chiari syndrome with a step-wise management. Hepatology. 2013 May;57(5):1962–8. https://doi.org/10.1002/hep.26306.
32. Abraldes JG, Gilabert R, Turnes J, Nicolau C, Berzigotti A, Aponte J, Bru C, Bosch J, García-Pagán JC. Utility of color Doppler ultrasonography predicting tips dysfunction. Am J Gastroenterol. 2005 Dec;100(12):2696–701.
33. Mukund A, Pargewar SS, Desai SN, Rajesh S, Sarin SK. Changes in liver congestion in patients with Budd-Chiari syndrome following endovascular interventions: assessment with transient elastography. J Vasc Interv Radiol. 2017 May;28(5):683–7. https://doi.org/10.1016/j.jvir.2016.11.091.
34. Mukund A, Sarin SK. Budd-Chiari syndrome: a focussed and collaborative approach. Hepatol Int. 2018 Nov;12(6):483–6. https://doi.org/10.1007/s12072-018-9900-z.
35. Salem R, Vouche M, Baker T, Herrero JI, Caicedo JC, Fryer J, Hickey R, Habib A, Abecassis M, Koller F, Vogelzang R, Desai K, Thornburg B, Hohlastos E, Resnick S, Lewandowski RJ, Sato K, Ryu RK, Ganger D, Kulik L. Pretransplant portal vein recanalization-transjugular intrahepatic portosystemic shunt in patients with complete Obliterative portal vein thrombosis. Transplantation. 2015 Nov;99(11):2347–55. https://doi.org/10.1097/TP.0000000000000729.
36. Thornburg B, Desai K, Hickey R, Kulik L, Ganger D, Baker T, Abecassis M, Lewandowski RJ, Salem R. Portal vein recanalization and transjugular intrahepatic portosystemic shunt creation for chronic portal vein thrombosis: technical considerations. Tech Vasc Interv Radiol. 2016 Mar;19(1):52–60. https://doi.org/10.1053/j.tvir.2016.01.006.

9 IR Management of Nonmalignant Portal Vein Thrombosis

Arpit Taunk and Amar Mukund

Abbreviations

PVT	Portal vein thrombosis (Nonmalignant)
TIPS	Transjugular intrahepatic portosystemic shunt
IVC	Inferior vena cava
rtPA	Recombinant tissue plasminogen activator

9.1 Introduction

Portal vein thrombosis (PVT) is defined as thrombus in main portal vein, which may or may not extend into branches of portal vein, the mesenteric vein, or splenic vein. PVT is seen in 10–25% of cirrhotics, thus not rare. PVT might lead to the worsening of liver functions. PVT increases the risk of complication associated with cirrhosis. In addition, the presence of PVT leads to increase in morbidity and mortality in patients receiving liver transplant and extensive PVT may even pose as a contraindication for transplantation, especially when the thrombus involves the splenomesenteric confluence. Various treatments are available for management of symptomatic PVT like systemic anticoagulation therapy, local fibrinolysis using urokinase or recombinant plasminogen activators (rtPA), mechanical recanalization by balloon plasty, balloon plasty, and local fibrinolysis followed by placement of TIPS stent. Recently, TIPS has played a major role in treating PVT in decompensated cirrhotics. The clinical efficacy and positive outcomes of TIPS have been confirmed in cirrhotic patients with PVT. Now the clinical indications of TIPS have been expanded from refractory ascites and pleural effusion in cirrhotics to acute and uncontrollable gastrointestinal bleeding and recurrent gastrointestinal bleeding, Budd–Chiari syndrome with or without concomitant PVT. [1–7]

9.2 Radiological Interventions in Nonmalignant Portal Vein Thrombosis

The decision on the treatment of cirrhotic with PVT depends essentially on the presenting symptoms, the age of the patient, any underlying comorbidities, and the extent of thrombus in portal vein /splenic vein/ mesenteric vein. The first step is to treat the underlying disease to reduce the risk of recurrent PVT thrombus. In asymptomatic patients with PVT, regular follow-up is recommended [8]. Portal vein recanalization should be done in the symptomatic patient [9, 10]. Additionally, in case of portal hypertension,

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embolization of collateral veins leads to improvement of portal flow, which in turn reduces the risk of portal vein re-thrombosis [6, 11–13]. Symptomatic PVT can be treated by several methods depending on the underlying disease and age of thrombus (acute or chronic). Various therapeutic interventions are (1) mechanical recanalization, (2) catheter-directed fibrinolysis, (3) systemic thrombolysis, or (4) surgical. The approach for mechanical recanalization is rarely transhepatic (except in non-cirrhotics with PVT and normal coagulation parameters where transhepatic route is preferred, (Fig. 9.1) [14–16]

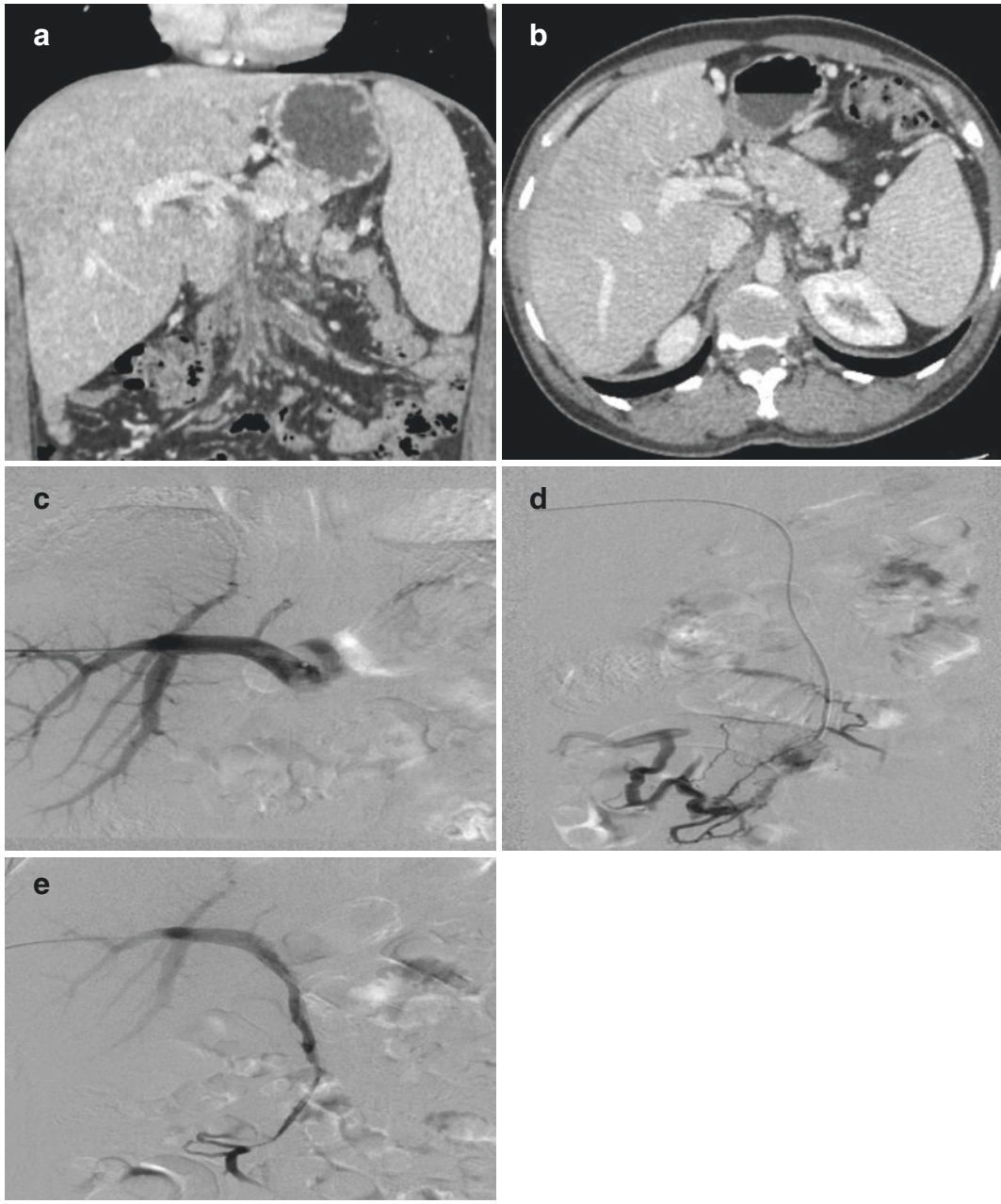

Fig. 9.1 Forty year male presented with acute abdominal pain. Contrast CT scan (**a**, **b**) showed non-cirrhotic liver with <50% occlusion of main portal vein and near complete occlusion of superior mesenteric vein. Portal venogram (**c, d**) through transhepatic route the same findings. Venogram post fibrinolysis (**e**) shows adequate opacification of portal vein and its branches and superior mesenteric vein suggestive of successful transhepatic recanalization

and is usually transjugular [17–19]. In cirrhotic patients with PVT, mechanical recanalization by balloon plasty and catheter-directed fibrinolysis are usually combined with TIPS to increase the flow of blood in the portal vein thus reducing the re-thrombosis risk (Figs. 9.2, 9.3, and 9.4). TIPS apart from treating PVT also helps in resolution of symptoms of decompensated cirrhotics.

In symptomatic non-cirrhotic patients with PVT, with no ascites, and with normal coagulation parameters, transhepatic route is may be taken for portal vein recanalization (Fig. 9.1). Transhepatic approach is easy and quick, moreover it provides better catheter maneuverability for recanalizing long segment thrombosis of PV and/or SMV. Alternatively transsplenic route may be taken for patients with difficult transhepatic access as a last resort, further the splenic track needs to be carefully embolized using glue/coils to avoid any hemorrhage/hematoma. In non-cirrhotics with PVT, ascites, and deranged coagulation parameters, transjugular route should be taken for portal vein recanalization to prevent the risk of hemoperitoneum, which may be associated with transhepatic/transsplenic approach [18, 20, 21]. Figure 9.5 represents the protocol for the management of PVT.

9.3 Mechanical Recanalization

Balloon angioplasty through transjugular route is relatively safe approach for recanalization of portal vein. Balloon plasty helps in maceration of thrombus hence improved thrombo-suction and lumen recanalization. If the thrombus has extended into portal vein branches, TIPS is combined with angioplasty to create good venous flow. In cases of chronic PVT, transjugular

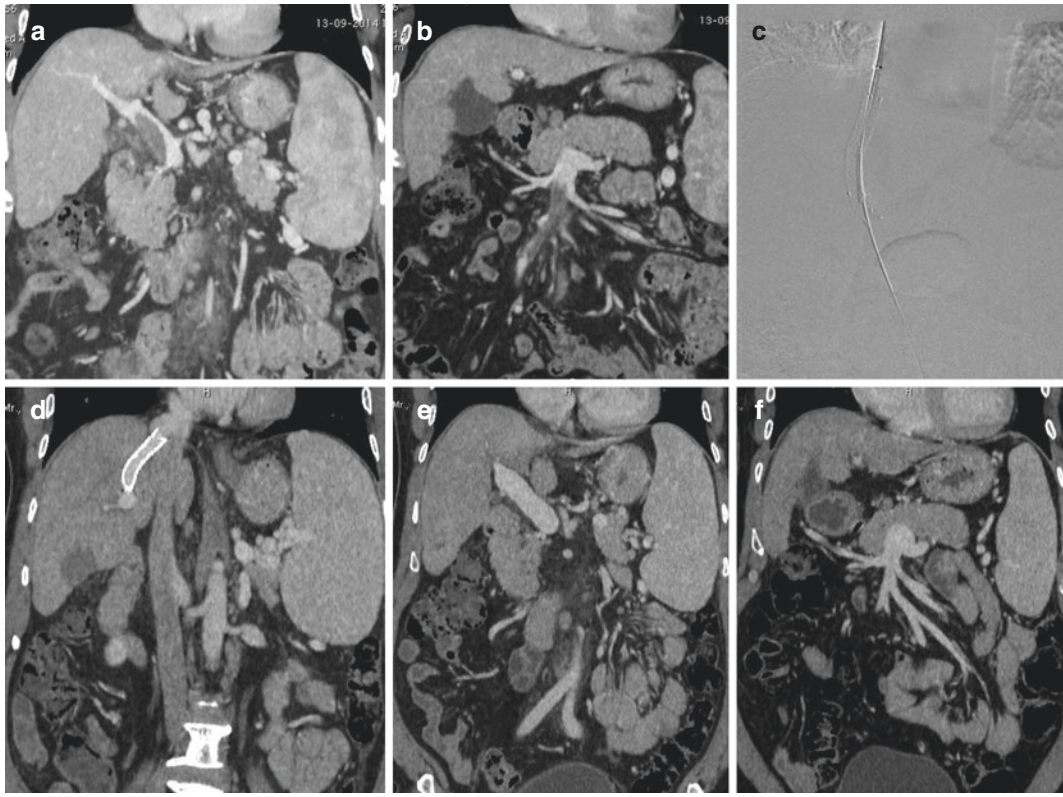

Fig. 9.2 Sixty-one-year-old male with cirrhosis (Hepatitis B related) presented with refractory UGI bleed. Contrast CT scan (**a, b**) showed thrombus in portal vein involving >75% of lumen with thrombus extending into superior mesenteric vein. This patient underwent TIPS in combination with local fibrinolysis by urokinase (**c**). His symptoms subsided after TIPS with no further episodes of UGI bleed. Contrast CT scan done (**d, e, f**) at 1 month post-procedure showed patent stent with complete recanalization of portal vein and superior mesenteric vein

approach is sometimes difficult. In such cases, transhepatic or transsplenic approach can be attempted, as it offers a better maneuvering of catheters into the occluded portal vein as compared to transjugular approach; however, transhepatic/transsplenic approaches have higher risk of development of hemoperitoneum, hence adequate care should be taken to prevent any hemorrhage [14, 18–20].

9.4 Local Pharmacological Fibrinolysis/Thrombolysis

It is performed in cases of symptomatic acute PVT through transjugular or transhepatic approach. Catheter is usually placed in main portal vein and rarely in superior mesenteric vein. Preferred thrombolytic is either rtPA or urokinase. Nolte et al. [22] and Leebeek et al. [23] placed TIPS stent first fol-

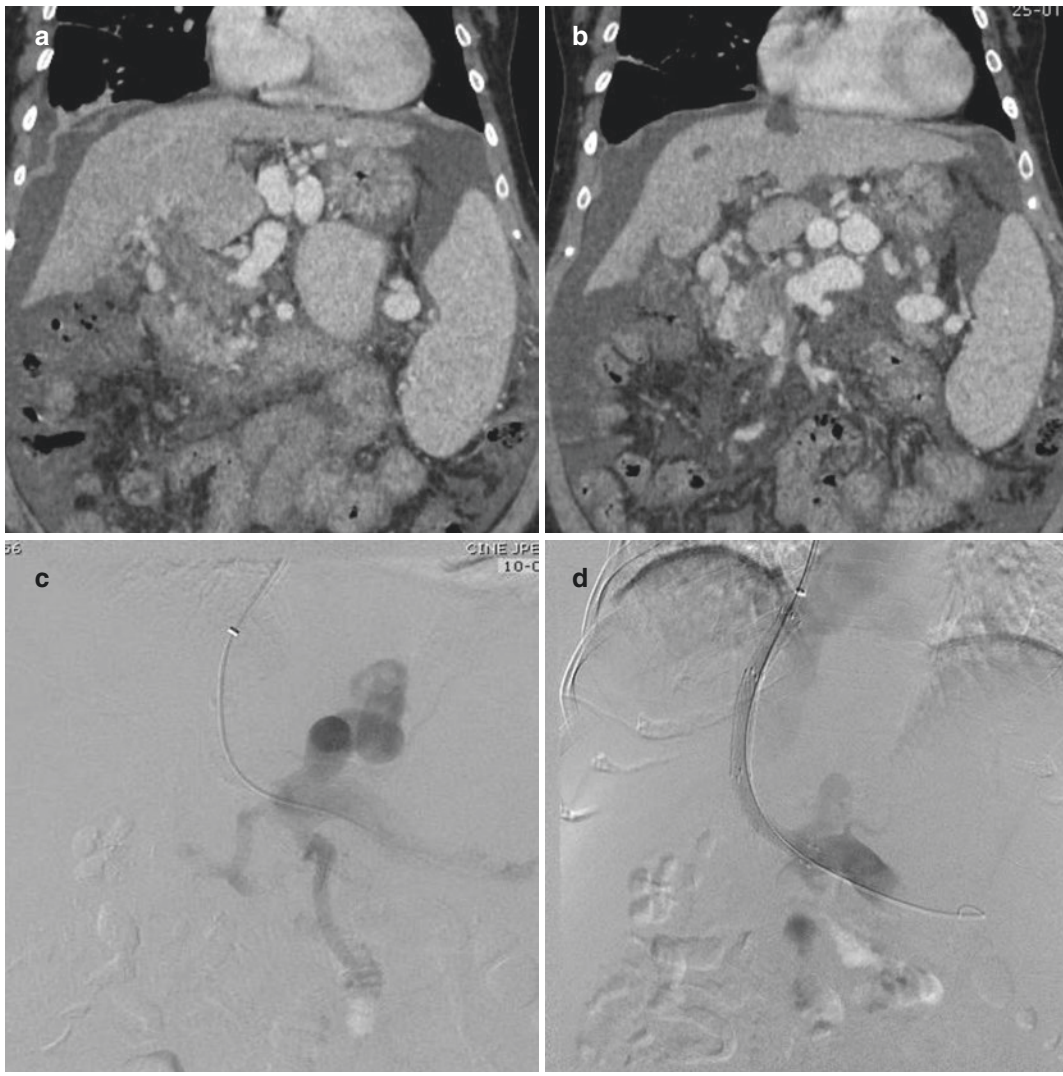

Fig. 9.3 Sixty-two-year female, case of cirrhosis (NASH related, CHILD B, MELD 12) with portal hypertension presented with refractory esophageal variceal bleed. Contrast CT scan (as shown in **a, b**) showed complete thrombosis of portal vein with extension of thrombus in superior mesenteric vein. TIPS was done in this patient in combination with balloon plasty (mechanical recanalization) and local fibrinolysis by urokinase. Contrast portogram (**c**) showed large esophageal varices. Post TIPS venogram (**d**) showed good opacification of portal vein and stent. Patient had no further episode of upper GI bleed post-procedure. Contrast Ct done after 1 month (**e, f, g**) showed good opacification of stent, portal vein, and superior mesenteric vein suggestive of complete recanalization

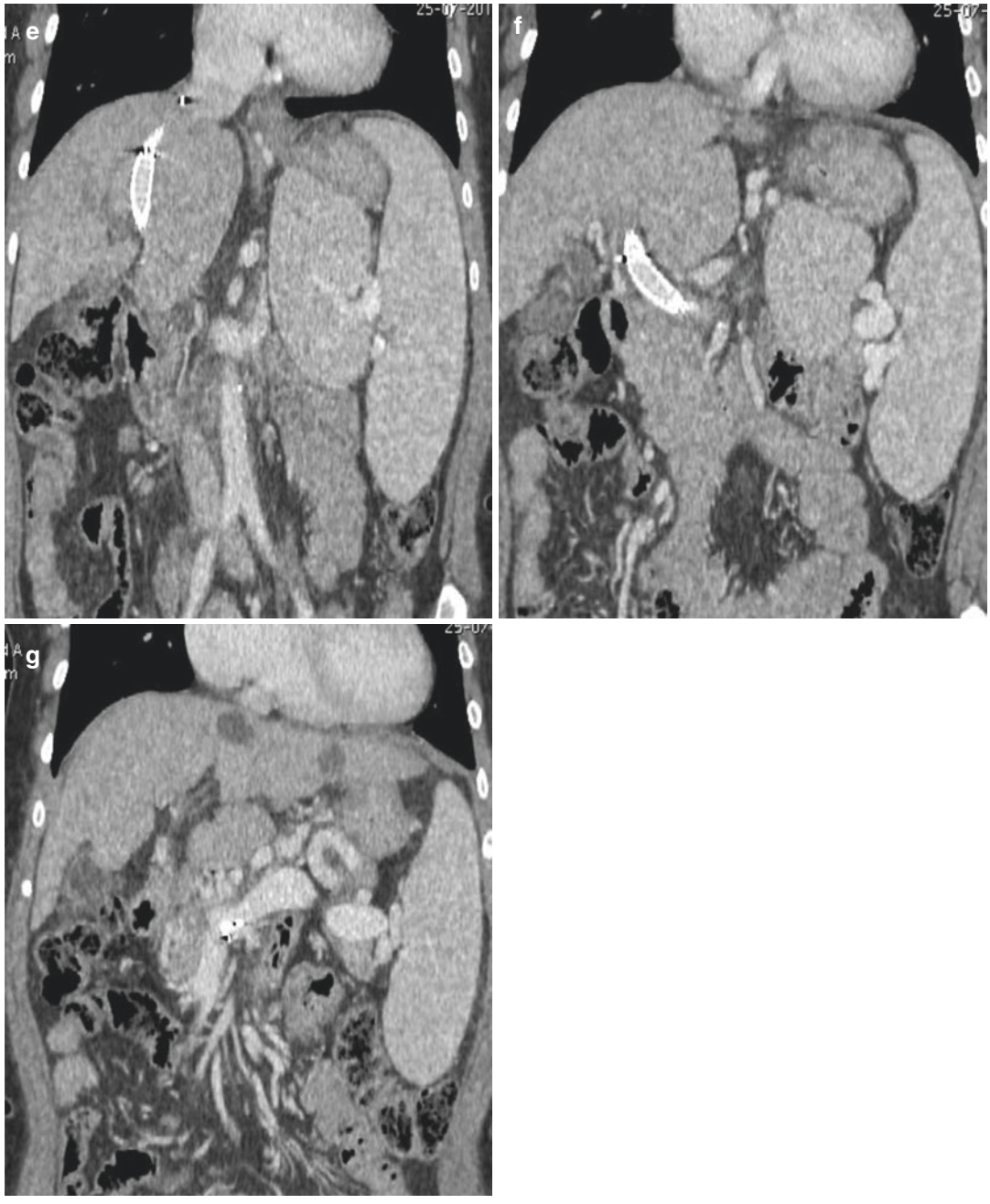

Fig. 9.3 (continued)

lowed by local catheter-directed thrombolysis. Mann et al. [20] performed catheter-directed thrombolysis first followed by placement of TIPS stent. The duration of administering local fibrinolytic therapy may range from minutes to few days based on portography findings [24]. The success rate of thrombus resolution by thrombolysis is high when the thrombus is acute (less than 14 days). Catheter-directed transarterial administration of thrombolytic drug is another approach, where cath-

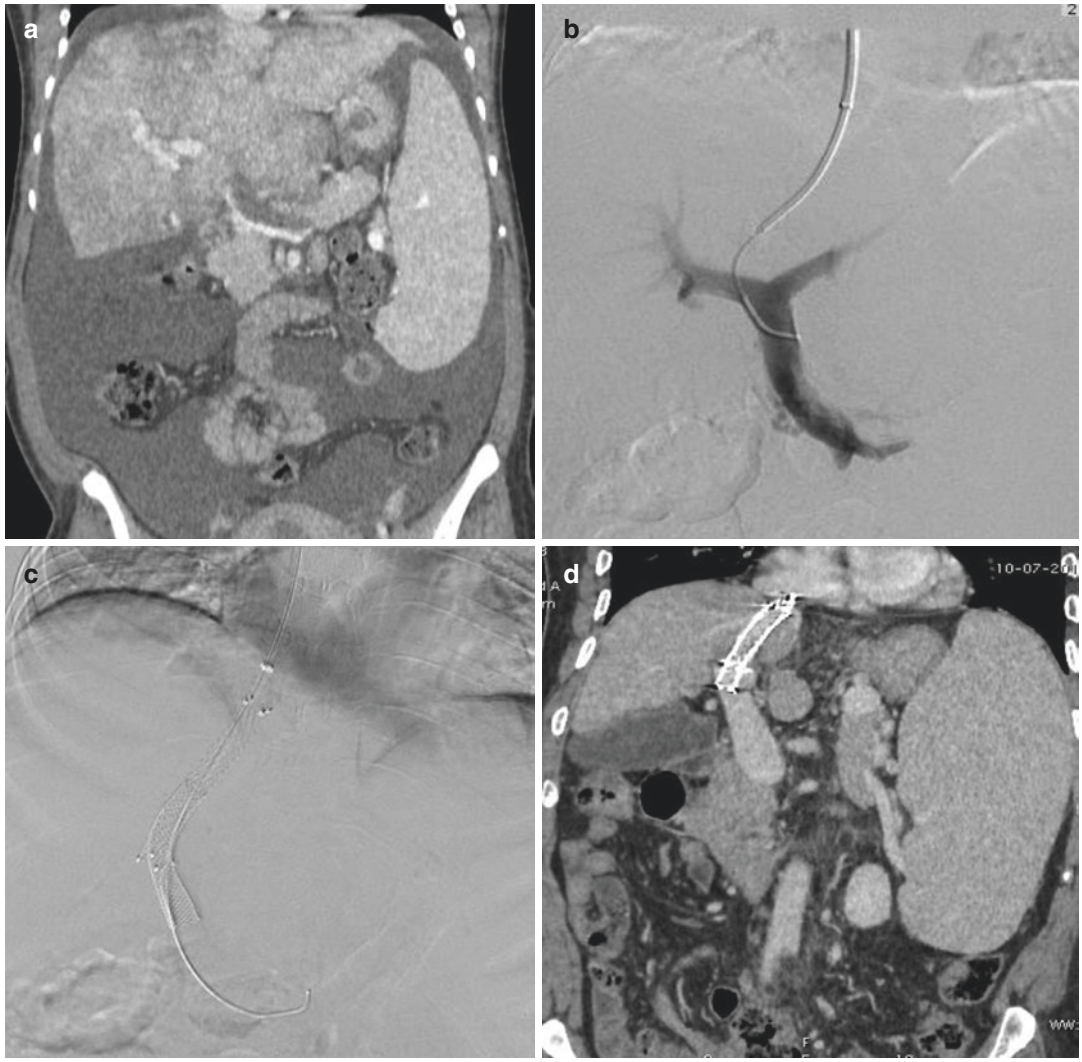

Fig. 9.4 Sixty year male with cirrhosis (NASH related) and refractory ascites. Contrast Ct scan (**a**) showed >90% occlusion of portal vein. Portal venogram (**b**) through transjugular route showed near complete recanalization of portal vein (post local fibrinolysis) followed by placement of TIPS (**c**) stent. Contrast CT done at 3 month follow-up (**d**) showed complete resolution of portal vein thrombus with resolution of ascites

eter tip is placed in the superior mesenteric artery for infusion of thrombolytic agent [26–30].

9.5 Combination of Mechanical Recanalization and Local Pharmacological Fibrinolysis

In most of the cases, resolution and recanalization of portal vein are better when mechanical recanalization and thrombolysis are combined together. This is particularly seen in post-liver transplant patient where stenosis persists at anastomotic site despite local fibrinolysis. Some authors practice mechanical recanalization by balloon angioplasty first followed by thrombolysis, whereas others prefer vice-versa [15, 19, 31, 32]. Once the recanalization is achieved, decision for placement of TIPS stent may be considered depending upon the residual thrombus load and underlying cause for the PVT.

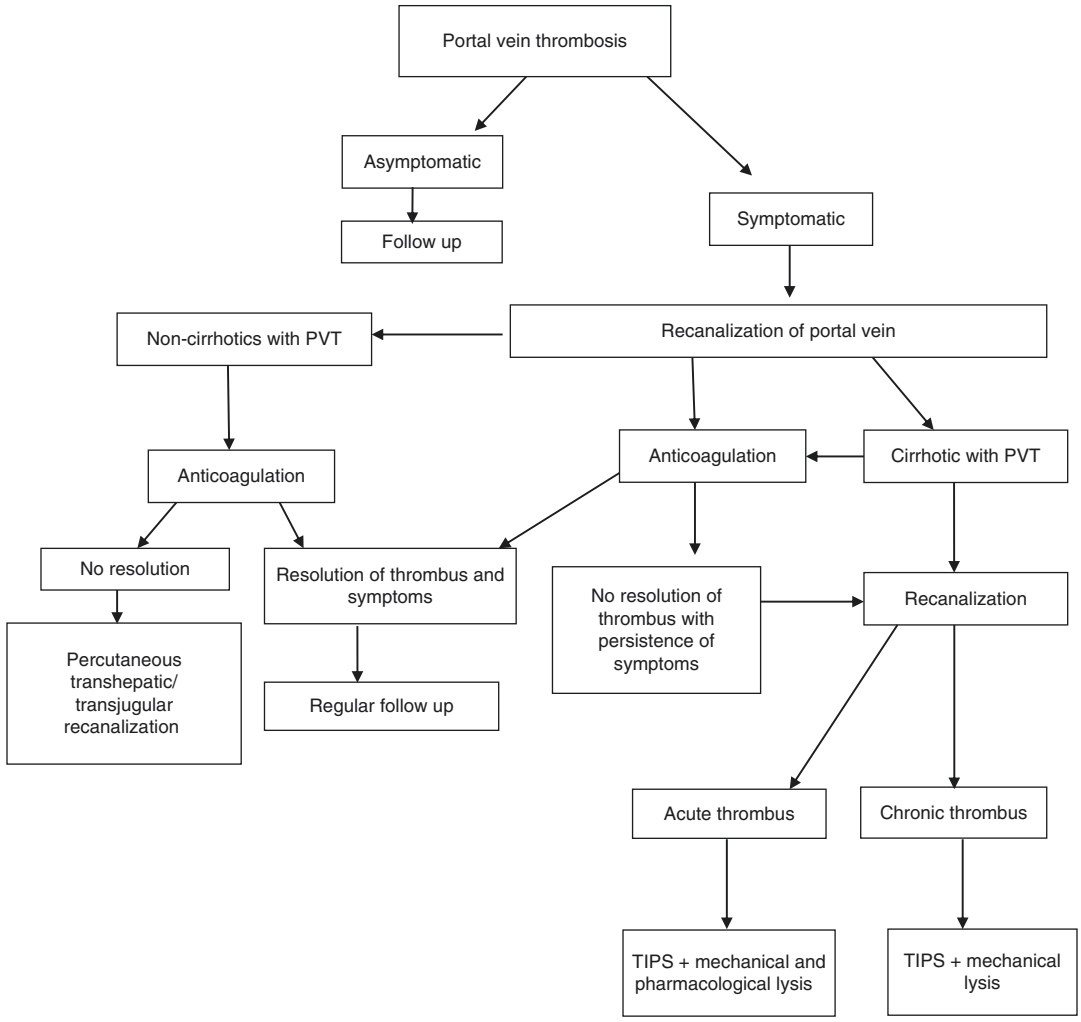

Fig. 9.5 Diagrammatic representation of radiological interventional management of portal vein thrombosis

9.6 Indications and Contraindication for Placement of TIPS Stent in PVT

9.6.1 Indications [33]

1. Liver cirrhosis with PVT with following underlying clinical status:
2. Acute esophageal variceal bleeding refractory to endoscopic therapy
3. Secondary prevention of esophageal variceal bleeding
4. Hepatorenal syndrome
5. Budd–Chiari syndrome
6. Portal hypertensive gastropathy
7. Hepato-pulmonary syndrome

9.6.2 Contraindication [33]

9.6.2.1 Absolute Contraindications

1. Esophageal variceal bleed—Primary prevention
2. Severe congestive heart failure
3. Severe pulmonary hypertension (mean pulmonary pressure > 45 mm of Hg)
4. Tricuspid regurgitation

5. Multiple liver cysts
6. Uncontrolled systemic infection/sepsis
7. Unrelieved biliary obstruction

9.6.2.2 Relative Contraindications

1. Hepatoma, particularly if central
2. Hepatic encephalopathy
3. Severe coagulopathy (INR >5)
4. Severe Thrombocytopenia (<20,000 platelets /mm^3)
5. Progression of thrombosed portal vein trunk into fibrotic cord
6. Severe hepatic insufficiency (SGOP or SGPT level or the total bilirubin level is threefold above the upper limit of normal)
7. Renal insufficiency (serum creatinine level is 1.5 times above the upper limit of normal)

9.7 Procedural Technique of Mechanical Portal Vein Recanalization, Local Fibrinolysis, and TIPS (Fig. 9.1, 9.2, and 9.3)

TIPS may be considered in cases of PVT with extensive thrombus load and complete/near complete occlusion of the spleno-portal axis. TIPS should be placed after restoring portal flow (atleast partial, if not complete) using pharmacological and/or mechanical thrombolysis. TIPS is usually performed through a transjugular approach whenever feasible. Alternatively transsplenic portal vein recanalization followed by TIPS is recently described for non-cirrhotic patients having extrahepatic portal vein obstruction (EHPVO) and portal cavernoma. In patients with patent intrahepatic portal vein, TIPS may be performed through transjugular route. In most of the cases, the right hepatic vein is used to access portal vein. When hepatic vein is thrombosed/occluded (in cases of Budd–Chiari syndrome), the portal vein is accessed directly from the IVC. A Colapinto needle is used to puncture the posterior branch of right portal vein preferably under ultrasound /fluoroscopic guidance. Care is taken to avoid capsular transgression of needle and prevent hemoperitoneum. After puncturing the portal vein, a J tip floppy guide wire (Radifocus, Terumo) is advanced across the thrombus with its tip placed in the distal splenic vein or superior mesenteric vein. Later floppy guidewire is replaced by Amplatz stiff wire. The liver parenchymal tract is dilated by 8 mm or 10 mm balloon followed by thrombo-suction with or without maceration of the thrombus [combined mechanical (balloon plasty) and local pharmacological fibrinolysis (heparin and urokinase)]. Later, a covered stent of appropriate length is placed in the entire hepatic tract measured using catheter with markers for calibration. After placement of covered stent another overlapping uncovered stent is placed into the portal vein. The tip of uncovered stent is placed 2 cm inside the main portal vein. Repeat balloon plasty of stent is done followed by contrast angiogram to confirm good flow across the TIPS stent. If thrombus is seen persisting in either portal vein, splenic vein, or superior mesenteric vein then thrombolysis can be continued (for 24–48 h) and a check angiogram is performed every 12 h to look for resolution of thrombus. The pressure gradient should be recorded before and after the procedure in all the patients (Table 9.1). In patients with portal cavernoma and no amenable portal vein branches, main portal vein is recanalised through transsplenic approach and a snare is placed in right branch of portal vein. The colapinto needle is advanced to target the snare and after succesful placement of colapito needle within the snare, wire from jugular access is advanced into the snare and pulled out through the splenic access and TIPS is performed. Additional thrombolysis may be performed if needed.

Table 9.1 Depicts the accessories used for the procedure

1. Routine sized vascular access sheath usually 6F sheath
2. 0.035-in. floppy J tip guide wire
3. RUPS set consisting of 10F Long sheath, cannula, Colapinto needle
4. 5F Multipurpose catheter
5. Amplatz Ultrastiff metallic guidewire
6. Covered and uncovered stent Graft
7. Balloon angioplasty catheters (8 mm /10 mm)
8. Balloon Inflation device
9. Urokinase /r-tPA and heparin

9.8 Discussion

PVT is often silent. On the other side, patient with symptomatic PVT may present with life-threatening complications. Sometimes the presence of PVT alone is not necessarily the primary cause for the deterioration of patient symptoms. This clinical deterioration may be either due to recent development of PVT or because of progression of cirrhosis with an episode of decompensation. The endovascular approach aims at restoring portal vein patency, which may result in relieving symptoms. Various techniques and approaches for management of PVT have been published. The most common studied approach is placement of TIPS stent with/without mechanical recanalization, with/without catheter-directed thrombolysis [32, 34].

In a study by Rossi et al. best results were obtained when mechanical recanalization by balloon angioplasty was performed followed by thrombolysis [34] and TIPS stent can be placed in the portal vein to increase the flow and prevent risk of portal vein re-thrombosis [14, 19, 32].

Blum et al. [18] performed mechanical recanalization by balloon angioplasty in the thrombosed segment of portal vein through transjugular approach followed by TIPS placement and thrombolysis. Priority should be given to transjugular access over transhepatic approach, as risk of hemorrhage is less in transjugular approach [31, 35]. If transjugular approach for mechanical recanalization of PVT fails, e.g., in chronic PVT, recanalization by transhepatic approach should be attempted [36, 37].

TIPS has a major role to play in cirrhotics with PVT as it ensures fast flow of blood in portal vein, thus reducing the risk of portal vein re-thrombosis. The other advantage of TIPS is that, it can be used as an access for re-intervention [18, 20, 38]. In some cases, due to difficult venous anatomy or in patients with chronic PVT with cavernous transformation, TIPS becomes technically difficult. In such cases combination of transjugular and transhepatic approach can be used for TIPS stent placement [10, 25].

In situations where portal venous system is completely thrombosed, authors recommend, catheter-directed intra-arterial administration of fibrinolytic agents through superior mesenteric artery. The concept behind intra-arterial administration is that arterial flow forces the lytic agent to act over the intraportal thrombus over a large surface area thus helping in clot lysis [29].

According to the study by Condat et al. [39], acute onset thrombosis is diagnosed when the following criteria are met: (1) Recent onset pain in the abdomen, (2) No signs and symptoms of chronic long-standing portal hypertension like gastrointestinal bleeding, ascites, portosystemic collaterals, collaterals at porta hepatis or splenomegaly. In such cases, most of the times, systemic anticoagulation therapy with heparin successfully recanalize the portal vein [39, 40].

Endovascular management of PVT should be considered if anticoagulation therapy gives unsatisfactory results with persistence of symptoms or there is a contraindication to anticoagulation therapy. In cirrhotics with symptomatic PVT, TIPS along with mechanical recanalization and/or local fibrinolysis should be done. TIPS aims at facilitating the portal flow and by reducing portal pressure, thus increasing portal flow, which in turn reduces the risk of re-thrombosis. The use of systemic thrombolytic therapy for the management of PVT is not usually recommended [41–44].

Once TIPS is placed, the recanalization rates are excellent with up to 80% partial or complete resolution of thrombus [45–48]. In one study, [49] residual portal vein thrombus was present in 77% of cases on imaging study done immediately after TIPS placement, while, on 1-month follow-up after the TIPS procedure, complete resolution of thrombus was seen in 76% cases suggesting that resolution of thrombus is due to increased flow in the portal vein after stent placement.

Special attention should be given in patient who may undergo liver transplantation post TIPS, as TIPS stent placed deep in to the portal vein or IVC makes the surgical anastomosis at portal vein and IVC complex [50–54]. The largest study to date showed that patient with PVT, who had TIPS stent placed prior to liver transplant, had improved graft survival [54].

9.9 Conclusion

At present, anticoagulation, local fibrinolysis, and TIPS combined with local fibrinolysis are the various treatment options in patients with PVT of various etiologies. In patients with prothrombotic disorders, anticoagulation, and endovascular catheter-directed thrombolysis are more beneficial for resolving portal vein thrombus. In contrast, TIPS with or without mechanical recanalization, with/without local fibrinolysis, has been performed for the treatment of acute/chronic PVT in decompensated cirrhotics.

References

1. Liu FY, et al. Interventional treatment for symptomatic acute-subacute portal and superior mesenteric vein thrombosis. World J Gastroenterol. 2009;15:5028–34.
2. Parikh S, Shah R, Kapoor P. Portal vein thrombosis. Am J Med. 2010;123:111–9.
3. Dhanasekaran R, et al. Transjugular intrahepatic portosystemic shunt for symptomatic refractory hepatic hydrothorax in patients with cirrhosis. Am J Gastroenterol. 2010;105:635–41.
4. Darwish Murad S, et al. Etiology, management, and outcome of the Budd-Chiari syndrome. Ann Intern Med. 2009;151:167–75.
5. Chevallier P, et al. Hepatopulmonary syndrome successfully treated with transjugular intrahepatic portosystemic shunt: a three-year follow-up. J Vasc Interv Radiol. 2004;15:647–8.
6. Han G, et al. Transjugular intrahepatic portosystemic shunt for portal vein thrombosis with symptomatic portal hypertension in liver cirrhosis. J Hepatol. 2011;54:78–88.
7. Goykhman Y, et al. Transjugular intrahepatic portosystemic shunt: current indications, patient selection and results. Isr Med Assoc J. 2010;12:687–91.
8. Lomas DJ, Britton PD, Alexander GJM, Calne RY. A comparison of MR and duplex Doppler ultrasound for vascular assessment prior to orthotopic liver transplantation. Clin Radiol. 1994;49:307–10.
9. Ganger DP, Klapman JB, McDonald V, Matalon TA, Kaur S, Rosenblate H, et al. Transjugular intrahepatic portosystemic shunt (TIPS) for Budd-Chiari syndrome or portal vein thrombosis. Am J Gastroenterol. 1999;94:603–8.
10. Walser EM, McNees SW, Dela Pena O, Crow WN, Morgan RA, Soloway R, et al. Portal venous thrombosis: percutaneous therapy and outcome. J Vasc Interv Radiol. 1998;9:119–27.
11. Cohen J, Edelmann RR, Chopra S. Portal vein thrombosis: a review. Am J Med. 1992;92:173–82.
12. Janssen HLA. Changing perspectives in portal vein thrombosis. Scand J Gastroenterol Suppl. 2000;232:69–73.
13. Chen H, Turon F, Hernandez-Gea V, et al. Nontumoral portal vein thrombosis in patients awaiting liver transplantation. Liver Transpl. 2016;22:352–65.
14. Baccarani U, Gasparini D, Risaliti A, Vianello V, Adani GL, Sainz M, et al. Percutaneous mechanical fragmentation and stent placement for the treatment of early posttransplantation portal vein thrombosis. Transplantation. 2001;72(9):1572–82.
15. Bilbao JL, Arias M, Herrero JL, Iglesias A, Regueira FM, AIejandre PL, et al. Percutaneous transhepatic treatment of a posttransplant portal vein thrombosis and a preexisting spontaneous splenorenal shunt. Cardiovasc Intervent Radiol. 1995;18:323–6.
16. Bilbao JL, Rodriguez-Cabello J, Longo JM, Zornoza G, Pramo J, Lecumberri FJ. Portal thrombosis: percutaneous transhepatic treatment with urokinase – a case report. Gastrointest Radiol. 1989;14:326–8.
17. Bilbao JL, Longo JM, Rousseau H, de Villa V, Mansilla F, Alvarez-Cienfuegos J, et al. Transjugular intrahepatic portocaval shunt after thrombus disruption in partially thrombosed portal veins. Cardiovasc Intervent Radiol. 1994;17:106–9.
18. Blum U, Haag K, Rössle M, Ochs A, Gabelmann A, Boos S, et al. Noncavernomatous portal vein thrombosis in hepatic cirrhosis: treatment with transjugular intrahepatic portosystemic shunt and local thrombolysis. Radiology. 1995;195:153–7.
19. Cherukuri R, Haskai ZJ, Naji A, Shaked A. Percutaneous thrombolysis and stent placement for the treatment of portal vein thrombosis after liver transplantation. Transplantation. 1998;65:1124–37.
20. Mann O, Haag K, Hauenstein KH, Rössle M, Pausch J. Septic portal vein thrombosis: successful treatment by local fibrinolysis and transjugular portosysternic stent shunt (TIPS). Dtsch Med Wschr. 1995;120:1201–6.
21. Vogl T, Hidajat N, Schroder RJ, Felix R. Recanalisation of an extended fresh thrombosis of portal vein with transjugular intrahepatic portosystemic stent shunt (TIPS). Fortschr Roentgenstr. 1999;171:163–5.
22. Nolte W, Figulla HR, Ringe B, Wiltfang J, Mnke H, Hartmann H, et al. Transjugular intrahepatic portosystemic shunt (TIPSS) in Budd-Chiari syndrome with portal vein thrombosis. Dtsch Med Wochenschr. 1997;122:116–21.
23. Leebeek FWG, Lameris JS, Buuren HR, Gomez E, Madretsma S, Sonneveld P. Budd-Chiari syndrome, portal vein and mesenteric vein thrombosis in a patient homozygous for factor V Leiden mutation treated by TIPS and thrombolysis. Br J Haematol. 1998;102:929–31.
24. Bizollon T, Bissuel F, Detry L, Trepo C. Fibrinolytic therapy for portal vein thrombosis. Lancet. 1991;337:1416.
25. Haskal ZJ, Duszak R Jr, Furth EE. Transjugular intrahepatic transcaval portosystemic shunt: the gun-sight approach. J Vasc Interv Radiol. 1996;7:139–42.

26. Antoch G, Taleb N, Hansen O, Stock W. Transarterial thrombolysis of portal and mesenteric vein thrombosis: a promising alternative to common therapy. Eur J Vasc Endovasc Surg. 2001;21:471–2.
27. Ludwig DJ, Hauptmann E, Rosoff L, Neuzil D. Mesenteric and portal vein thrombosis in a young patient with protein S deficiency treated with urokinase via the superior mesenteric artery. J Vasc Surg. 1999;30:551–4.
28. Mies S, Alfieri F, Fischer D, Raia S. Portal vein thrombosis repermeabilization with r-tPA. Thromb Haemost. 1991;65:108.
29. Poplausky MR, Kaufman JA, Geller SC, Waltman AC. Mesenteric venous thrombosis treated with urokinase via the superior mesenteric artery. Gastroenterology. 1996;110:1633–5.
30. Tsujikawa T, Ihara T, Sasaki M, Inoue H, Fujiyama Y, Bamba T. Effectiveness of combined anticoagulant therapy for extending portal vein thrombosis in Crohn's disease. Report of a case. Dis Colon Rectum. 1996;39:823–5.
31. Durham D, LaBerge JM, Altman S, Kam I, Everson GT, Gordon RL, et al. Portal vein thrombolysis and closure of competitive shunts following liver transplantation. J Vasc Interv Radiol. 1994;5:611–8.
32. Haskal ZJ, Naji A. Treatment of portal vein thrombosis after liver transplantation with percutaneous thrombolysis and stent placement. J Vasc Interv Radiol. 1993;4:789–92.
33. Copelan A, Kapoor B, Sands M. Transjugular intrahepatic portosystemic shunt:indications, contraindications, and patient work-up. Semin Interv Radiol. 2014 Sep;31(3):235–42. https://doi.org/10.1055/s-0034-1382790.
34. Rossi C, Zambruni A, Ansaloni F, Casadei A, Morelli C, Bernardi M, et al. Combined mechanical and pharmacological thrombolysis for portal vein thrombosis in liver-graft recipients and in candidates for liver transplantation. Transplantation. 2004;78:938–40.
35. Aytekin C, Boyvat F, Kurt A, Yologlu Z, Coskun M. Catheter-directed thrombolysis with transjugular access in portal vein thrombosis secondary to pancreatitis. Eur J Radiol. 2001;39:80–2.
36. Malkowski P, Pawlak J, Michalowicz B, Szczerban J, Wroblewski T, Leowska E, et al. Thrombolytic treatment of portal thrombosis. Hepatogastroenterology. 2003;50:2098–100.
37. Radosevich PM, Ring EJ, LaBerge JM, Peltzer MY, Haskal ZJ, Doherty MM, et al. Transjugular intrahepatic portosystemic shunts in patients with portal vein occlusion. Radiology. 1993;186:523–7.
38. Uflacker R. Applications of percutaneous mechanical thrombectomy in transjugular intrahepatic portosystemic shunt and portal vein thrombosis. Tech Vasc Interv Radiol. 2003;6:59–69.
39. Condat B, Pessione F, Denninger MH, Hillaire S, Valla D. Recent portal or mesenteric venous thrombosis: increased recognition and frequent recanalization on anticoagulant therapy. Hepatology. 2000;32:466–70.
40. Sheen CL, Lamparelli A, Milne A, Green L, Ramage JK. Clinical features, diagnosis and outcome of acute portal vein thrombosis. Q J Med. 2000;93:531–4.
41. Frey R, Suter B. Portal vein and hepatic vein thrombosis in occult myeloproliferative syndrome. Progression of thrombosis under heparin therapy. Schweiz Med Wschr. 1996;126:1437–41.
42. Schultheiß M, Bettinger D, Thimme R. Nonsurgical therapeutic options in portal vein thrombosis. Viszeralmedizin. 2014;30:388–92.
43. Rössle M. TIPS: 25 years later. J Hepatol. 2013;59:1081–93.
44. Luca A, Miraglia R, Caruso S, et al. Short- and long-term effects of the transjugular intrahepatic portosystemic shunt on portal vein thrombosis in patients with cirrhosis. Gut. 2011;60:846–52.
45. Senzolo M, Tibbals J, Cholongitas E, et al. Transjugular intrahepatic portosystemic shunt for portal vein thrombosis with and without cavernous transformation. Aliment Pharmacol Ther. 2006;23:767–75.
46. Han G, Qi X, He C, et al. Transjugular intrahepatic portosystemic shunt for portal vein thrombosis with symptomatic portal hypertension in liver cirrhosis. J Hepatol. 2011;54:78–88.
47. Salem R, Vouche M, Baker T, et al. Pretransplant portal vein recanalization-transjugular intrahepatic portosystemic shunt in patients with complete obliterative portal vein thrombosis. Transplantation. 2015;99:2347–55.
48. Primignani M, Tosetti G, La Mura V. Therapeutic and clinical aspects of portal vein thrombosis in patients with cirrhosis. World J Hepatol. 2015;7:2906–12.
49. Rössle M, Bausch B, Klinger C. Therapy algorithm for portal vein thrombosis in liver cirrhosis: the internist's point of view. Viszeralmedizin. 2014;30:401–8.
50. Clavien PA, Selzner M, Tuttle-Newhall JE, et al. Liver transplantation complicated by misplaced TIPS in the portal vein. Ann Surg. 1998;227:440–5.
51. D'Avola D, Bilbao JI, Zozaya G, et al. Efficacy of transjugular intrahepatic portosystemic shunt to prevent total portal vein thrombosis in cirrhotic patients awaiting for liver transplantation. Transplant Proc. 2012;44:2603–5.
52. Tripathi D, Therapondos G, Redhead DN, et al. Transjugular intrahepatic portosystemic stent-shunt and its effects on orthotopic liver transplantation. Eur J Gastroenterol Hepatol. 2002;14:827–32.
53. Guerrini GP, Pleguezuelo M, Maimone S, et al. Impact of tips preliver transplantation for the outcome post-transplantation. Am J Transplant. 2009;9:192–200.
54. Barbier L, Hardwigsen J, Borentain P, et al. Impact of transjugular intrahepatic portosystemic shunting on liver transplantation: 12-year single-center experience. Clin Res Hepatol Gastroenterol. 2014;38:155–63.

10 Preoperative Interventions: Portal Vein Embolization

Aniket Mondal and Amar Mukund

10.1 Introduction

Complete surgical removal of the hepatic tumor remains the most essential aspect of curative treatment of hepatobiliary malignancies [1]. It includes both primary and metastatic lesion and gives the patient the sole likelihood of long-term survival [1]. The extent and degree of hepatic resection depend on multiple characteristics of tumor-like size, location, and burden, along with the morphological and functional status of the liver. Frequently, major hepatectomy may be required for curative radical tumor resection [2, 3]. The explanation behind unresectability might be inadequate future liver remnant (FLR) volume leading to postoperative liver failure, that alone is the primary reason for postoperative demise after major hepatectomy [4]. In patients having diffuse hepatic ailment (for example, cirrhosis) undergoing a major hepatic resection, the mortality increases up to 32%, whereas in patient with normal liver parenchyma, mortality ranges from 3.2 to 7% [2, 5, 6]. The size of FLR volume is most significant determinant leading to postoperative liver failure. Preoperative portal vein embolization (PVE) of the resectable hepatic segments reduces the hazard of postoperative liver failure even after extensive hepatectomy. Further, it increases the number of patients who may undergo such extensive resection [1, 2, 5, 6]. This section would discuss about the principle of PVE, anatomy of hepatic vasculature to be known before PVE, indications and contraindications, techniques, embolic agents, and complications of this procedure.

10.2 Principle of PVE

The high regenerative capability of liver parenchyma is the concept behind portal vein embolization [7]. In 1920, Rous et al. found that ligation of portal vein caused atrophy of the same side of liver parenchyma along with enlargement of contralateral lobe in rabbits [7, 8]. Since the last two decades, preoperative PVE has been widely used for suitable patients having hepatobiliary malignancies before extensive hepatic resection. Selective segmental portal vein embolization of diseased part of the liver can induce atrophy of the resectable hepatic segments along with enlargement of the future liver remnant. Following PVE, the total function of the liver is progressively accelerated toward the FLR segments, making the patient suitable to adjust the modification of portal pressure before the surgery, thus, reduces the morbidity and mortality following the major hep-

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atectomy [9]. The resultant increase in the FLR volume makes the unresectable tumor resectable and brings down the hazards of postoperative hepatic insufficiency and hepatic failure [1, 2, 6].

10.3 Portal Vein Anatomy and its Variants

A thorough understanding of hepatic segmental anatomy is very important for the proper execution of PVE [1, 2]. The Couinaud classification is the most widely used system to described functional liver anatomy, where the liver is divided into eight segments on the basis of hepatic and portal vein branching [1, 2, 10].

The main portal vein originates in the retroperitoneum behind the neck of the pancreas generally formed by joining of the superior mesenteric vein and the splenic vein (splenomesenteric confluence) and ascends along the hepatoduodenal ligaments to porta hepatis [1, 2, 11]. Main portal vein usually divides into the right and left portal vein in extrahepatic region (incidence~48%), but it can be intrahepatic (~26%) or at the hepatic gateway (~26%) [1, 2, 12]. The right portal vein (RPV) usually divides into two branches—anterior sectoral branch (supplying segment V & VIII) and posterior sectoral branch (supplying segment VI &VII), whereas left portal vein (LPV) divides into the horizontal portion (extrahepatic course) and umbilical portion (intrahepatic course) [2, 13, 14]. The main branches of left portal vein usually supply the segment II, III, and IV of liver, arising from the umbilical portion [2, 14].

The incidence of anatomical variation of the PV branching is not common and ranges from 10–15%, however, recognition of their presence before PVE may be valuable for successful PVE or hepatectomy [2, 15]. The trifurcation of main portal vein is most common variation (incidence ~11%), in which the main portal vein divides into three branches—left portal vein, right anterior, and right posterior branch [2, 16]. Quadrifurcation of portal vein is very rare variant, in which it divides into four branches—left portal vein, right anterior portal vein, and two branches supplying segment VI and VII [1, 2, 16]. Duplication or absence right portal vein conjoined with a hypoplastic right hepatic lobe is a very rare anomaly. Rarely, inexistence of the extrahepatic portion of left portal vein is seen where a solitary portal vein gets in the right side of liver and traversing to the left, supplying only segmental portal vein branches along its path [16].

10.4 Indication of PVE

PVE is indicated when future liver remnant (FLR) after liver resection is very small or borderline in size to provide essential liver functions [1]. Various factors determining the outcome of PVE in terms of adequate hypertrophy should be evaluated prior to the procedure [2, 17]. First, the proportion of FLR to total estimated liver volume (TELV) should be determined. Second, the evaluation of hidden liver ailment needs to be done as patients with diffuse liver parenchymal disease need larger FLR than otherwise healthy liver. Third, as patient having larger body mass needs larger FLRs than smaller patient, so patient body size must be considered before PVE. Fourth, evaluation of underlying systemic disease must be done, for example, diabetes mellitus can mitigate hepatic hypertrophy as insulin plays the role of comitogenic factor with hepatocyte growth factor (HGF) leading to slow pace of regeneration due to insulin resistance [5, 18]. Fifth, the type and degree of hepatic resection are vital in light of the facts that larger functional FLR might be a requisite to reduce postoperative morbidity.

Recommendations for performing PVE are: Anticipated FLR to be ≤ 20% in normal liver, FLR of ≤ 30% in patients with diffuse parenchymal disease (non-cirrhotic type) or with chemotherapy-associated steatohepatitis (CASH), nevertheless FLR of ≤ 40% in cirrhotic livers to accomplish the concerned benchmarks [1, 2, 19, 20, 21]**.**

Standardized FLR (sFLR) is calculated generally utilizing CT volumetry and measuring its contribution to the total liver volume as a ratio of the estimated total liver volume drawn from the patient's body surface area (BSA).

10.5 Contraindication of PVE

10.5.1 Absolute Contraindications

1. Established portal hypertension: Extensive hepatectomy is generally not reasonable in patients with diagnosed portal hypertension and hence PVE should not be performed [17].
2. Widespread thrombosis of portal veins in liver segment possessing the tumor—due to already diverted portal flow toward the FLR and proper distribution of embolic agent [14, 17].
3. Surgery is usually not performed in patients having metastatic disease or peritoneal seeding, consequently PVE is not applicable in those patients [14].

10.5.2 Relative Contraindications

1. Uncorrectable coagulopathy.
2. Mild portal hypertension and advanced fibrosis—Although few earlier studies had shown restricted hypertrophy in patients with cirrhosis and fibrosis, newer studies have revealed a reasonable increase of FLR following PVE in patients with mild portal hypertension [22].
3. Biliary obstruction with biliary dilatation—In this condition, biliary drainage of the FLR may be considered prior to PVE.
4. Tumor precluding safe transhepatic access.
5. Renal insufficiency.

10.6 Preprocedural Work-Up and Procedural Details

10.6.1 Preoperative Work-Up

Preceding PVE, all clinical details need to be throughly evaluated. Relevant laboratory investigations like hemoglobin, white blood cells count, INR, liver function tests, and renal function tests are imperative before PVE. In patients having raised serum bilirubin levels due to biliary obstruction (more than 3.0 mg/dL), biliary drainage should be performed either percutaneously or endoscopically for symptomatic relief as well as for effective FLR hypertrophy [1, 5]. Cross-sectional imaging either a CT or MRI is very important in making proper planning and design for productive PVE. Multiphasic CT or MRI is generally acquired ahead of PVE to assess the extension of hepatic lesion as well as to quantify the FLR volume and mapping the resectable hepatic segments. The proper assessment of the hepatic vascular anatomy especially the portal vein variations are very crucial for a successful PVE.

10.6.2 PVE Procedures

Access to the portal vein is one the important step in PVE, as it may be accessed via a mini-laparotomy for transileocolic route or percutaneous transhepatic route.

10.6.3 Transileocolic Approach

In 1990, Makuuchu et al. first described transileocolic portal vein embolization. In this technique, mini-laparotomy is required in the right lower quadrant of the abdomen for cannulating the ileocolic vein. Thereafter, a catheter is advanced into the main portal vein and the desired intrahepatic portal vein branches for the embolization [23]. However, this being a more invasive procedure with associated morbidity, it did not gain widespread use due to the development of percutaneous transhepatic approach.

10.6.4 Transhepatic Approach

In transhepatic PVE a portal vein radicle is accessed percutaneously. It may be performed by two approaches—contralateral approach (embolizing right portal vein branches after obtaining access via left portal vein) or ipsilateral approach (embolizing RPV branches through RPV access only). The advantages and disadvantages of both the approaches are mentioned in Table 10.1 [1, 2, 5, 14].

Sedation

Generally, transhepatic PVE is carried out under mild sedation (using intravenous midazolam and fentanyl citrate) and a local anesthesia (using 1% lidocaine hydrochloride) at the puncture site for alleviating the regional pain [1, 2, 5, 14]. However, it could be performed under general anesthesia according to patient condition and operators' preferences.

Steps

Three basic steps are involved—(1) Accessibility to portal vein, (2) Flush portal venogram for venous anatomy, (3) Embolization of intrahepatic portal vein of selective hepatic segments.

The transhepatic PVE (both contralateral and ipsilateral route) is performed percutaneously, using ultrasound guidance for the puncture of portal vein. The basic steps for both the approaches are mostly similar. A 22-gage needle is mostly used to puncture the portal vein radicle and a guidewire, followed by a catheter is advanced in the main portal vein [2, 5, 24]. Thereafter, a 5F or 6F vascular access sheath is placed with in the portal vein for further catheter exchange. In contralateral approach, segment 3 portal vein branch is usually chosen for puncture, as it is more anterior and easily visible on ultrasound, also it allows easy access to segment IV portal vein ramifications if needed. In ipsilateral PVE, the right anterior sectoral portal vein is preferred over the right posterior sectoral vein, as fewer complications are seen with this approach [5, 25].

A 5F catheter (usually KMP/MPA/C2 catheter, Cook, Bloomington, IN) is used to catheterize segmental branches of the portal vein (Both contralateral and ipsilateral PVE) (Fig. 10.1). The acute angulation of portal vein branches can cause difficulty in catheterization of right sectoral portal vein branches during ipsilateral approach, hence reverse curve catheters (like SIM-1/C-1, Cook) or balloon occlusion catheters with multiple lumen might be required.

Flush portography is then carried out with a 5F catheter (KMP/MPA catheter, Cook) placed in the main portal vein for mapping of portal venous tree. The 15 degree right anteroposterior (RAP) view displays better visualization of the portal vein ramifications.

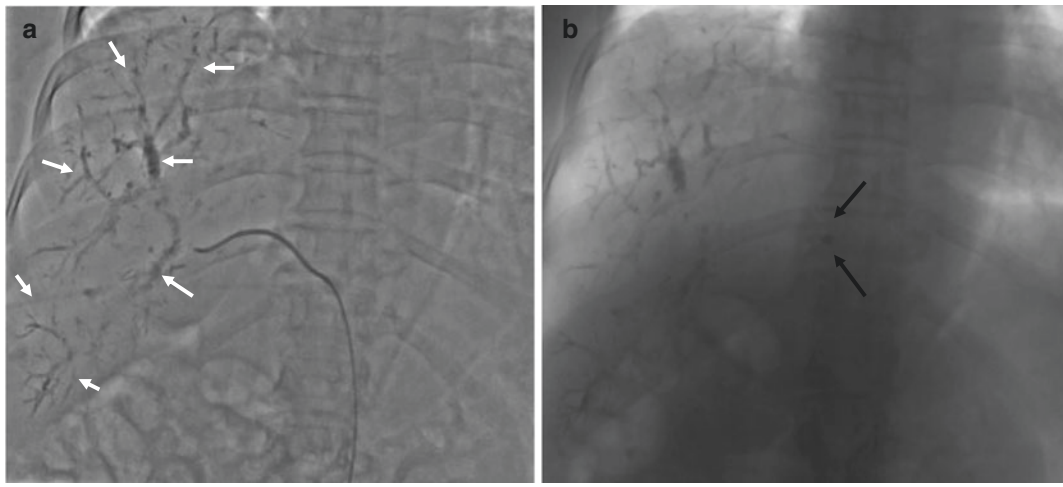

Fig. 10.1 Fluoroscopic image (**a**) shows contralateral approach for PVE using glue mixed with lipiodol as embolizing agent within the right PV branches (white arrows), (**b**) shows post PVE track embolization using coil (black arrows)

In patients with normal liver, estimation of portal venous pressure is not commonly recommended, whereas it should be done in patients with chronic liver disease. Portal venous pressure gradient over 12 mmHg is regarded as a relative contraindication for hepatectomy [26].

Embolization is done after catheterizing sectoral portal veins of chosen hepatic segments. The choice of embolic agent depends on operator's preference. Total occlusion of target portal vein branches and diverting the blood flow toward the future remnant portal venous system is the end point of the embolization (Fig. 10.1). While embolizing the right main portal vein adequate stump (approx. 1 cm) should be left free of embolization to provide space for ligation while resection [1]. This also prevents the hazard of thrombus extension from right portal vein to the left.

Thereafter portal venogram is done to evaluate the completion of the PVE and as a check for any complication (Fig. 10.2). In patients having chronic hepatic ailment like cirrhosis, portal pressure should be measured to observe the change in pressure; the change in pressure should be around 3 mm Hg [26].

If extended right hepatectomy is planned, additional embolization of segment IV portal vein branches is recommended for maximum hypertrophy of segment II and III. In contralateral approach, embolization of segment IV portal vein branches are usually done after the embolization of right portal venous system, since this permits better delineation of segment IV portal branches as they become dilated and more conspicuous after right lobe embolization. Additionally, it diminishes the risk of dislodging the embolic agent during catheter handling. Whereas in ipsilateral approach, this process is typically carried out before the embolization of the right lobe, due to the potential possibility of dislodgement of embolic material from right to left lobe during catheter manipulation (Table 10.1).

After completing embolization, the catheter is delicately withdrawn to prevent the inadvertent dislodgement of any embolic agent to the future remnant. Lastly, during the removal of the access sheath, the tract is usually occluded with coils (Fig. 10.1) [5].

10.7 Embolic Materials

Presently, various embolic materials have been utilized for performing PVE such as gelfoam, polyvinyl alcohol (PVA) particles, coils, n-Butyl cyanoacrylate (NBCA), and absolute alcohol [1, 2, 14]. The best embolic material is supposed to induce complete occlusion of veins with no chance of recanalization. Nevertheless, there is no consensus regarding the best and safe embolic material for portal vein embolization. Hence, the decision of embolic agent depends on the user's choice and experience with the embolic substance, the available catheter for delivering the embolic agent, and the approach for PVE.

Gelfoam is a temporary embolic material and related with a rapid PV recanalization [2, 24]. PVA particles are a reasonably good embolizing agent and among them, spherical particles are more efficient than the nonspherical particles [2, 27]. Alcohol injection is described and is quite effective, but it is difficult to control and is associated with serious complication like parenchymal necrosis and venous thrombosis [21].

NBCA (glue) is one of the commonly used embolic agents for PVE. It causes permanent occlusion of portal vein by polymerizing rapidly (as it comes in contact with blood) [1, 2, 5, 28]. It is a radiolucent liquid which can be mixed with lipiodol for radio-opacity and controlling the rate of polymerization (Figs. 10.1 and 10.2). The proportion of glue to lipiodol ranges from 1:1 to 1:9 as briefed in previous studies [28]. For embolization of distal smaller veins, a higher dilution of glue with lipiodol is utilized [1, 2, 5, 28]. Multiple previous studies have shown NBCA to be very effective for preoperative portal vein embolization because it prompts both proximal and distal PV blockage and induces a periportal inflammatory reaction that could additionally act as a stimulus of future remnant liver regeneration [2, 5, 14, 28]. Flushing of the delivery catheter should be done with a nonionic solution (5% dextrose), just before and after injection of glue to prevent

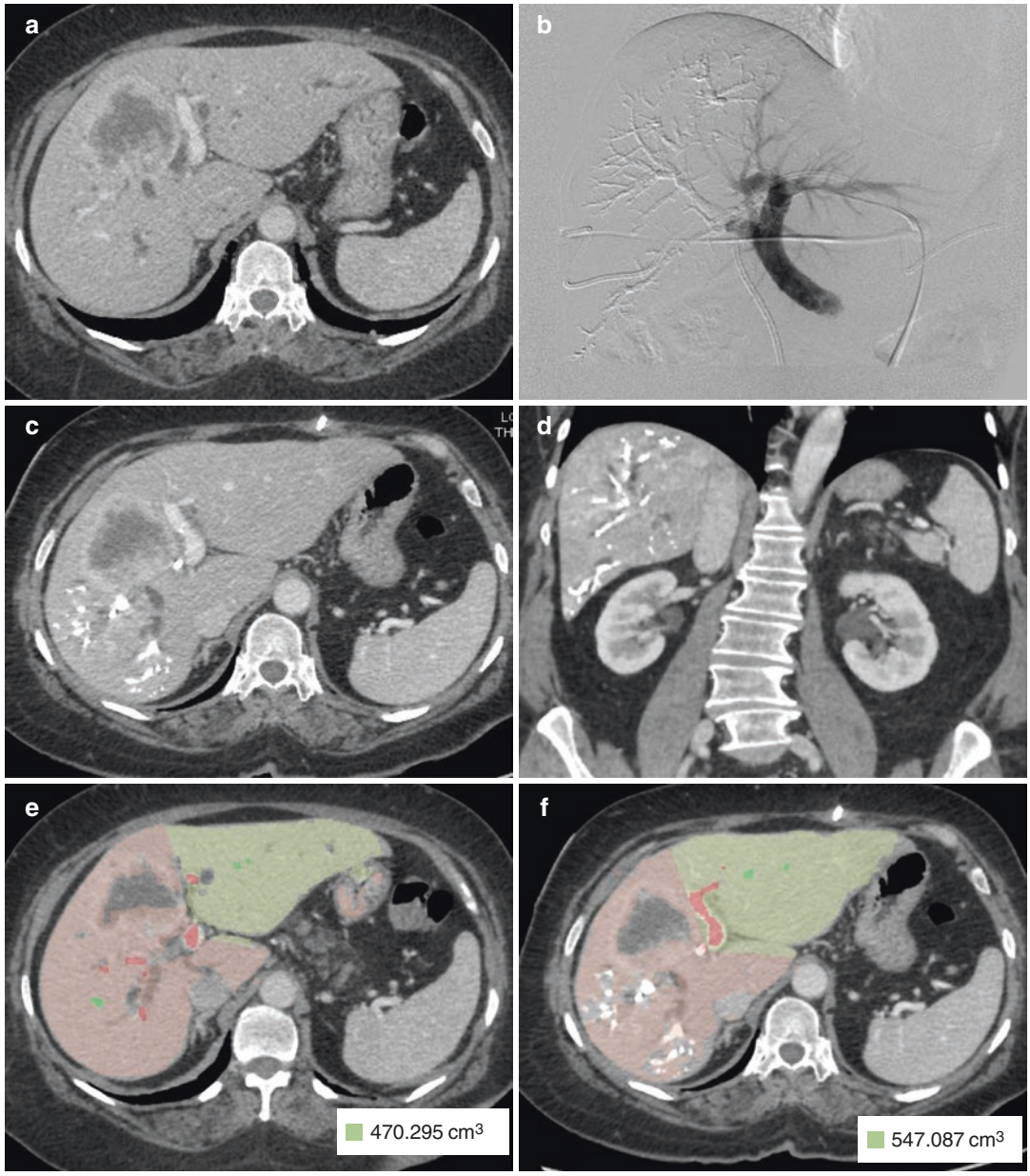

Fig. 10.2 A 60 year female patient with cholangiocarcinoma underwent right portal vein embolization using contralateral approach. (**a**) Pre PVE, axial cross-section CT section shows mass forming cholangiocarcinoma. (**b**) DSA image shows right PVE done via contralateral approach with contrast opacification of main and left portal vein. (**c** & **d**) Post PVE axial CT images show embolization of right portal vein and its segmental branches with hypertrophy of left lateral segment of liver. (**e**) Pre PVE & (**f**) Post PVE CT volumetry images show hypertrophy of left lateral segment of liver

catheter occlusion and non-target embolization. Administration of glue needs adequate experience and technical skill as it is difficult control owing to its liquidity and rapid polymerization [5, 28].

For PVE, spherical microparticles with coil embolization have shown to be superior to nonspherical PVA. Initially, embolization is usually performed with small sizes particles (100 to 500 μm) for embolization of distal smaller

Table 10.1 Advantage and disadvantage of different transhepatic approaches

Approach	Advantage	Disadvantage
Ipsilateral approach:	No injury to FLR No risk of injury to the left portal vein like thrombosis/ dissection due to catheterization Easy cannulation and embolization of segment IV branches	Due to sharp angulation of portal vein branches, cannulation of target portal vein may be technically challenging Chances of nontarget propagation of embolic substance in the process of final flush venography Risk of tumor seeding (rare)
Contralateral approach	Straighforward catherization of right anterior and posterior sectoral portal veins due to lack of acute angulation. No associated tumor cell seeding No risk of dislodgment of embolic agent during final venogram.	Risk of injury to FLR Difficulty in cannulation of segment IV branches

branches, followed by embolization with larger size particles (700 to 900 μm) for large proximal branch occlusion [29]. Coils can be employed at the cease of procedure to permit for the total blockage of proximal branch. Recently, vascular plugs have been used instead of coils for occluding the proximal right main portal vein or ahead of NBCA embolization by ipsilateral route to prevent backflow in the contralateral hepatic portal veins [30].

10.8 Hypertrophy Response

Multiphased contrast-enhanced CT or MRI is typically done ahead of PVE to assess the degree of tumor dissemination and to quantify the future hepatic remnant volume. CT volumetry is used for the estimation of FLR volume and TLV (total liver volume), in addition it provides comprehensive intrahepatic vascular and biliary anatomy as well as mapping for surgical resection [31]. FLR hypertrophy is usually measured after 3 to 5 weeks of PVE.

Previous studies have shown clinically significant regeneration to be associated with increase in the FLR ratio of 8% to 25% after PVE in patients having normal liver or liver metastases [1, 2, 5, 14, 27, 28, 32–34]. Although, as shown in few previous studies, PVE may not induce adequate FLR hypertrophy in about 20% of patients with liver cirrhosis. Hypertrophy of FLR is inversely proportional to the FLR ratio prior to PVE, implying that the lower FLR earlier to PVE will have the higher hypertrophy [2, 29]. Subsequently, there is no minimum threshold for the FLR ratio to carry out portal vein embolization.

10.9 Complication

PVE is a safe procedure and most patients do not develop any major complication related to PVE. However, based on previous studies, the complication can be categorized into major and minor complication (Table 10.2) [1, 2, 5, 14, 35, 36]. About 20% to 25% of patients may develop some minor self-limiting complication comprising of fever, pain, and abdominal discomfort. Major complications (Table 10.2) are rarely seen.

10.10 Additional Combined Strategies and Modification of PVE Technique

10.10.1 Sequential Arterial and Portal Venous Embolization

Despite technically successful PVE, definitive hepatectomy may not be possible in some cases due to the progression of tumor, deterioration of

Table 10.2 Complication of PVE

Minor complication:	1. Abdominal discomfort/pain 2. Fever 3. Elevation of liver enzymes (transaminitis) 4. Nausea and vomiting 5. Post-embolization syndrome (rare)
Major complication	1. Puncture related: (a) Vascular injury—Hemorrhage (sub-capsular hematoma or hemoperitoneum) and other vascular trauma such as arterio-venous fistula, pseudoaneurysm, transient hemobilia. (b) Biloma—Due to either intra- or extrahepatic bile duct damage. (c) Infection: Cholangitis, abscess, or systemic sepsis. (d) Pneumothorax—During intercostal puncture. 2. Embolization related: (a) Nontarget embolization in FLR (b) Hepatic infarction in the embolized segments (c) Venous thrombosis: Main portal vein or left portal vein thrombosis due to venous wall injury during catheter manipulation or propagation of thrombus from embolized segments. (d) Portal hypertension: Usually in cirrhotic patients with increased portal pressure following PVE could build the danger of gastroesophageal variceal disruption.

the general condition, and inadequate FLR growth. In such cases, patients with hepatocellular carcinoma (HCC), transarterial embolization (TAE) might be the additional remedial choice [36]. A previous study by Kang et al. demonstrated that superselective TAE prior to PVE was safe and efficacious [37]. Various small studies have shown arterial embolization of liver tumors after PVE is helpful in augmenting the hypertrophy of FLR.

10.11 Two-Stage Hepatectomy and PVE

Two-stage hepatic resection has been designed to accommodate patients with bilobar colorectal liver metastasis for surgical excision of tumor using PVE [36, 38, 39]. In the process of the primary phase, tumor inside the anticipated FLR is removed or in some cases ablated. When, the FLR is freed of tumor, PVE is carried out to expand the FLR volume. PVE is usually done between two steps of liver resection to increase FLR volume, as these patients mostly receive hepatotoxic neo-adjuvant chemotherapy. While sufficient FLR growth is accomplished, the second- stage hepatectomy is planned for the remaining metastases which may require a right or extended right hepatectomy [38, 39].

10.12 Novel Strategies for PVE

There are many novel approaches which have been developed with modification of PVE techniques to increase FLR hypertrophy and reduce complication. These include transarterial, transsinusoidal, and reversible PVE with an additional infusion of stem cells to the FLR segments following PVE [36].

10.13 Adjuvant Stem Cell Transplantation with PVE

Hematopoietic and mesenchymal stem cells may assume an important function in the remodeling of hepatic hypertrophy and can replenish impaired hepatocytes [40, 41]. A recent study showed that autologous hematopoietic CD133+ stem cells may enhance the volume of left lateral hepatic segments before the extended right hepatectomy. In the light of these results, investigators have studied the intra-portal injection of stem cells along with PVE to increase the speed of FLR hypertrophy [42].

10.14 Conclusions

Preoperative PVE is an effective procedure to augment hypertrophy of FLR and hence reduces postoperative complications. Owing to its high technical and clinical success it has a potential to convert unresectable patients of hepatobiliary malignancies due to small FLR into resectable disease. PVE is a safe procedure with a minimal procedure-related morbidity and insignificant mortality. A wide variety of embolic agents have been used for PVE. The blend of n-butyl cyanoacrylate and lipiodol and the alliance of PVA particles and coils are overwhelmingly utilized. PVE is increasingly being combined with emerging therapies in novel manners to improve and expedite the hypertrophy of FLR.

References

1. Orcutt ST, Kobayashi K, Sultenfuss M, Hailey BS, Sparks A, Satpathy B, Anaya DA. Portal vein embolization as an Oncosurgical strategy prior to major hepatic resection: anatomic, surgical, and technical considerations. Front Surg. 2016 Mar 11;3:14.
2. Loffory R, Favelier S, Chevallier O, et al. Preoperative portal vein embolization in liver cancer: indications, techniques and outcomes. Quant Imaging Med Surg. 2015 Oct;5(5):730–9.
3. Bakalakos EA, Kim JA, Young DC, Martin EW Jr. Determinants of survival following hepatic resection for metastatic colorectal cancer. World J Surg. 1998;22:399–404.
4. Fazakas J, Mándli T, Ther G, Arkossy M, Pap S, Füle B, et al. Evaluation of liver function for hepatic resection. Transplant Proc. 2006;38:798–800.
5. Mukund A, Mondal A, Patidar Y, Senthil K. Safety and outcomes of pre-operative portal vein embolization using N-butyl cyanoacrylate (glue) in hepatobiliary malignancies: a single center retrospective analysis. Indian J Radiol Imaging. 2019 Jan-Mar;29(1): 40–6.
6. Liu H, Fu Y. Portal vein embolization before major hepatectomy. World J Gastroenterol. 2005;11: 2051–4.
7. Hong YK, Choi SB, Lee KH, Park SW, Park YN, Choi JS, et al. The efficacy of portal vein embolization prior to right extended hemihepatectomy for hilar cholangiocellular carcinoma: a retrospective cohort study. Eur J Surg Oncol. 2011 Mar;37(3):237–44.
8. Rous P, Larimore LD. Relation of the portal blood to liver maintenance: a demonstration of liver atrophy conditional on compensation. J Exp Med. 1920;31:609–32.
9. Anaya DA, Blazer DG, Abdalla EK. Strategies for resection using portal vein embolization: hepatocellular carcinoma and hilar cholangiocarcinoma. Semin Intervent Radiol. 2008;25:110–22.
10. Couinaud C. Le foie: études anatomiques et chirurgicales. Paris, France: Masson; 1957. p. 75.
11. Okten RS, Kucukay F, Dedeoglu H, Akdogan M, Kacar S, Bostanci B, Olcer T. Branching patterns of the main portal vein: effect on estimated remnant liver volume in preoperative evaluation of donors for liver transplantation. Eur J Radio. 2012 Mar;81(3):478–83.
12. Schultz SR, LaBerge JM, Gordon RL, Warren RS. Anatomy of the portal vein bifurcation: intra- versus extrahepatic location--implications for transjugular intrahepatic portosystemic shunts. J Vasc Interv Radiol. 1994;5:457–9.
13. Yamane T, Mori K, Sakamoto K, Ikei S, Akagi M. Intrahepatic ramification of the portal vein in the right and caudate lobes of the liver. Acta Anat (Basel). 1988;133:162–72.
14. Madoff DC, Hicks ME, Vauthey JN, et al. Transhepatic portal vein embolization: anatomy, indications, and technical considerations. Radiographics. 2002;22:1063–76.
15. Atri M, Bret PM, Fraser-Hill MA. Intrahepatic portal venous variations: prevalence with US. Radiology. 1992;184:157–8.
16. Hardy KJ, Jones RM. Failure of the portal vein to bifurcate. Surgery. 1997;121:226–8.
17. Madoff DC, Abdalla EK, Vauthey JN. Portal vein embolization in preparation for major hepatic resection: evolution of a new standard of care. J Vasc Interv Radiol. 2005;16:779–90.
18. Nagino M, Nimura Y, Kamiya J, Kondo S, Uesaka K, Kin Y, Hayakawa N, Yamamoto H. Changes in hepatic lobe volume in biliary tract cancer patients after right portal vein embolization. Hepatology. 1995;21:434–9.
19. Vauthey JN, Chaoui A, Do KA, Bilimoria MM, Fenstermacher MJ, Charnsangavej C, et al. Standardized measurement of the future liver remnant prior to extended liver resection: methodology and clinical associations. Surgery. 2000;127:512–9.
20. Abdalla EK, Hicks ME, Vauthey JN. Portal vein embolization: rationale, technique and future prospects. Br J Surg. 2001;88:165–75.
21. Shimamura T, Nakajima Y, Une Y, Namieno T, Ogasawara K, Yamashita K, et al. Efficacy and safety of preoperative percutaneous transhepatic portal embolization with absolute ethanol: a clinical study. Surgery. 1997;121:135–41.
22. Denys A, Lacombe C, Schneider F, et al. Portal vein embolization with *N*-butyl cyanoacrylate before partial hepatectomy in patients with hepatocellular carcinoma and underlying cirrhosis or advanced fibrosis. J Vasc Interv Radiol. 2005;16:1667–74.
23. Makuuchi M, Thai BL, Takayasu K, et al. Preoperative portal vein embolization to increase safety of major hepatectomy for hilar bile duct carcinoma: a preliminary report. Surgery. 1990;107:521–7.

24. de Baere T, Roche A, Elias D, Lasser P, Lagrange C, Bousson V. Preoperative portal vein embolization for extension of hepatectomy indications. Hepatology. 1996;24:1386–91.
25. Kodama Y, Shimizu T, Endo H, Miyamoto N, Miyasaka K. Complications of percutaneous transhepatic portal vein embolization. J Vasc Interv Radiol. 2002;13:1233–7.
26. Bruix J, Castells A, Bosch J, et al. Surgical resection of hepatocellular carcinoma in cirrhotic patients: prognostic value of preoperative portal pressure. Gastroenterology. 1996;111:1018–22.
27. Madoff DC, Abdalla EK, Gupta S, Wu TT, Morris JS, Denys A, et al. Transhepatic ipsilateral right portal vein embolization extended to segment IV: improving hypertrophy and resection outcomes with spherical particles and coils. J Vasc Interv Radiol. 2005;16:215–25.
28. Wajswol E, Jazmati T, Contractor S, Kumar A. Portal vein embolization utilizing N-butyl cyanoacrylate for contralateral lobe hypertrophy prior to liver resection: a systematic review and meta-analysis. Cardiovasc Intervent Radiol. 2018 Sep;41(9):1302–12.
29. Denys A, Bize P, Demartines N, Deschamps F, De Baere T. Cardiovascular and interventional radiological Society of Europe. Quality improvement for portal vein embolization. Cardiovasc Intervent Radiol. 2010;33:452–6.
30. Libicher M, Herbrik M, Stippel D, Poggenborg J, Bovenschulte H, Schwabe H. Portal vein embolization using the amplatzer vascular plug II: preliminary results. Rofo. 2010;182:501–6.
31. Lim MC, Tan CH, Cai J, Zheng J, Kow AW. CT volumetry of the liver: where does it stand in clinical practice? Clin Radiol. 2014 Sep;69(9):887–95.
32. Tsoumakidou G, Theocharis S, Ptohis N, Alexopoulou E, Mantziaras G, Kelekis NL, et al. Liver hypertrophy after percutaneous portal vein embolization: comparison of N-butyl-2-cyanocrylate versus sodium acrylate-vinyl alcohol copolymer particles in a swine model. Cardiovasc Intervent Radiol. 2011;34:1042–9.
33. Guiu B, Bize P, Gunthern D, Demartines N, Halkic N, Denys A. Portal vein embolization before right hepatectomy: improved results using n-butyl-cyanoacrylate compared to microparticles plus coils. Cardiovasc Intervent Radiol. 2013;36:1306–12.
34. Jaberi A, Toor SS, Rajan DK, Mironov O, Kachura JR, Cleary SP, et al. Comparison of clinical outcomes following glue versus polyvinyl alcohol portal vein embolization for hypertrophy of the future liver remnant prior to right hepatectomy. J Vasc Interv Radiol. 2016;27:1897–905.
35. Yeom YK, Shin JH. Complication of portal vein embolization : evaluation on cross sectional imaging. Korean J Radiol. 2015 Sep-Oct;16(5):1079–85.
36. May BJ, Talenfeld AD, Madoff DC. Update on portal vein embolization : evidence-based outcomes, controversies, and novel strategies. J Vasc Interv Radiol. 2013 Feb;24(2):241–54.
37. Kang BK, Kim JH, Kim KM, Ko GY, Yoon HK, Gwon DI, et al. Transcatheter arterial chemoembolization for hepatocelluar carcinoma after attempted portal vein embolization in 25 patients. Am J Roentgenol. 2009 Nov;193(5):W446–51.
38. Jaeck D, Oussoultzoglou E, Rosso E, Greget M, Weber JC, Bachellier P. A two-stage hepatectomy procedure combined with portal vein embolization to achieve curative resection for initially unresectable multiple and bilobar colorectal liver metastases. Ann Surg. 2004;240:1037–49.
39. Narita M, Oussoultzoglou E, Bachellier P, Rosso E, Pessaux P, Jaeck D. Two-stage hepatectomy procedure to treat initially unresectable multiple bilobar colorectal liver metastases: technical aspects. Dig Surg. 2011;28:121–6.
40. Theise ND, Nimmakayalu M, Gardner R, et al. Liver from bone marrow in humans. Hepatology. 2000;32:11–6.
41. Korbling M, Katz RL, Khanna A, et al. Hepatocytes and epithelial cells of donor origin in recipients of peripheral-blood stem cells. N Engl J Med. 2002;346:738–46.
42. Gehling UM, Willems M, Dandri M, et al. Partial hepatectomy induces mobilization of a unique population of haematopoietic progenitor cells in human healthy liver donors. J Hepatol. 2005;43:845–53.

11 Ablation of Liver and Biliary Tumors

Pankaj Gupta and Naveen Kalra

11.1 Introduction

Image-guided ablative therapy represents an important interventional radiological method for the treatment of liver tumors and to some extent biliary tumors. There are several ablative techniques currently available (Table 11.1). The most widely used ablative technique is radiofrequency ablation (RFA). Recently, microwave ablation (MWA) and cryoablation are being increasingly utilized. Irreversible electroporation (IRE) is utilized in special situations. The chemical methods of ablation including percutaneous ethanol injection (PEI) and percutaneous acetic acid injection (PAI) are no longer recommended, except in a resource-limited setting [1].

Ablation provides a curative option in patients with resectable hepatocellular carcinoma (HCC), where it compares favorably with surgical resection, particularly for lesions <2 cm [2]. Ablation is also commonly utilized in combination with transarterial chemoembolization (TACE) in patients with unresectable HCC. Ablation is also recommended for oligometastases from colorectal and other cancers. Endobiliary RFA can be performed via percutaneous or endoscopic route [3]. Percutaneous RFA is performed for malignant biliary obstruction caused by perihilar involvement by cholangiocarcinoma or gallbladder cancer [4]. The various indications of ablative therapies are discussed in detail in the section below.

Table 11.1 Various ablative methods

Chemical	Thermal	Nonthermal
Percutaneous ethanol injection (PEI) Percutaneous acetic acid injection (PAI)	*Heat* • Radiofrequency ablation (RFA) • Microwave ablation (MWA) • High intensity focused ultrasound (HIFU) • Laser induced thermotherapy (LITT)	Irreversible electroporation (IRE)
	Freezing • Cryoablation (CA)	

11.2 Ablative Therapies: Classification

The various ablative methods are broadly classified on the basis of mechanism of cellular action into chemical, thermal, and non-chemical nonthermal. Among the ablative methods listed in

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Table 11.1, RFA, MWA, CA, and IRE are the most commonly used methods. The mechanism of cell damage, indications, contraindications, technical details, and current status of the commonly used methods will be discussed in this chapter.

Indications of Ablation of Liver Tumors [5]

A. Primary tumors
   Hepatocellular carcinoma
- Resectable: Very early (single lesion <2 cm) and early HCC (single lesion or up to three lesions each less than 3 cm)
- Unresectable: In combination with transarterial chemoembolization
- Bridging therapy for liver transplant
- Recurrent HCC
  Intrahepatic cholangiocarcinoma

B. Metastatic tumors (oligometastatic disease, lesion size < 3cm) from:
   - Colorectal cancer
   - Neuroendocrine tumor
   - Pancreatic carcinoma
   - Cholangiocarcinoma
   - Breast cancer
   - Gastric cancer

Indications of Ablation of Biliary Tumors

Ablative therapy is indicated for malignant biliary obstruction caused by unresectable cholangiocarcinoma, gallbladder cancer, pancreatic cancer, intraductal papillary mucinous neoplasm, and metastatic disease [4]. An additional indication is stent occlusion [6].

11.3 Contraindications [1]

11.3.1 Liver Tumor Ablation

11.3.1.1 Absolute

- Uncorrectable coagulopathy
- Biliary dilatation
- Intravascular invasion
- Exophytic tumor
- Tumor within 1 cm of the main bile duct

Relative

- Child–Pugh C cirrhosis
- Hepatic failure
- Pacemaker/defibrillator
- Platelet count<50,000/mm^3

Biliary Tumor Ablation

- Uncorrectable coagulopathy
- Systemic infection, sepsis

11.4 Technical Aspects

11.4.1 Pre-Procedure Preparation

1. Informed written consent
2. Investigations: complete blood count, coagulogram, liver, and renal function tests
3. Imaging: multiphase CT or MRI performed within 4 weeks of the procedure
4. Fasting for at least 6 hours prior to the procedure

11.4.2 Image Guidance for Ablation

Ablative therapies can be performed through percutaneous, laparoscopic, and intraoperative methods. However, percutaneous method is the most widely utilized. The percutaneous procedures are guided by an imaging method. Ultrasound, CT, and MRI can all be utilized. However, ultrasound and CT are the most popular imaging techniques for this purpose. Some institutes prefer CT over ultrasound and vice versa. The need for precise placement of multiple probes during IRE mandates the utilization of CT for guidance. Similarly, when performing MWA using multiple applicators, CT guidance is preferred for accurate placement.

11.4.3 Real-Time Monitoring

During RFA and MWA, hyperechoic foci are caused by microbubbles and gas released from the target tissue on ultrasound [7]. This may lead to an overestimation of the size of the ablation zone. Moreover, the precise localization of the probe during the procedure may be difficult

and requires considerable expertise. This hyperechogenicity typically disappears by 1 h. CT allows precise visualization of the ablation and early detection of any complication. The ice ball produced during cryoablation is well visualized on ultrasound, CT, and MRI. However, the posterior acoustic shadowing produced on ultrasound limits its utilization. CT, on the other hand, allows complete visualization of the ice ball [8].

11.4.4 Prevention of Damage to Adjacent Structures

To reduce damage to adjacent structures during ablative procedures, hydrodissection is the most common method. It employs carbon dioxide or 5% dextrose to separate the vital structures from the tumor [9]. The visualization of CT may be improved by adding iodinated contrast in the fluid in a ratio of 1:50. The other methods are carbon dioxide insufflation, balloon placement, and use of thermoprotective gel [10].

11.4.5 Intraoperative Monitoring

Standard cardiac, oxygen, and blood pressure monitoring are required. RFA, MWA, and CA can be performed under conscious sedation or general anesthesia (GA), although the former is preferred. IRE involves muscle blockade for muscle relaxation and strict cardiac monitoring for any arrhythmias and is always performed under GA.

11.4.6 Assessment of Technical Effectiveness

The ablative procedure is considered to be technically effective when the entire tumor and a safety margin is covered in the ablation zone. A safety margin is a 5 to 10 mm tissue adjacent to the tumor margin that may harbor micrometastases or microscopic foci of tumor [10].

11.5 RFA

11.5.1 Mechanism of Ablation

Cell death by RFA involves alternating current at frequencies of 400 MHz. This induces ionic agitation and generation of heat by friction. Following heating, the tissues respond in a similar fashion regardless of the method of thermal ablation [11]. With mild elevation of temperature (to ~40 °C), cellular homeostasis can be maintained. With hyperthermia (42–45 °C), the susceptibility of cells to other cytotoxic agents such as chemotherapy increases [11]. Irreversible cellular damage occurs when temperatures are increased to 46 °C for 60 min [11]. With further increase in temperature to 50–52 °C, cell death is achieved in 4–6 min. Between 60° and 100 °C, instantaneous cell death occurs. Temperatures >105 °C cause vaporization, and carbonization. Thus, to achieve optimal ablation, the aim is to achieve a temperature of 50–100 °C in the entire volume of target tissue.

11.5.2 Hardware (Figs. 11.1 and 11.2)

A basic RF equipment comprises a RF generator capable of producing alternating current, electrode (probe), and a grounding pad [12]. The grounding pad (placed on the patient's thighs or back) acts as a large dispersive electrode. It allows the current to pass freely without causing any significant heat production. At the electrode point, desiccation and charring of the superficial tissue occur. Bipolar electrodes do not require placement of grounding pads.

Four types of RF electrodes are commercially available [12]. There are two models of retractable-needle electrodes (model 70 and model 90 Star-burst XL needles, RITA Medical Systems, Mountain View, CA; LeVeen needle electrode, Boston Scientific, Boston, MA). These electrodes have multiple curved electrodes of varying length that assume the shape of a "Christmas tree" or "umbrella" upon deployment. Third type is an internally cooled electrode (Cool-Tip RF electrode; Medtronics,

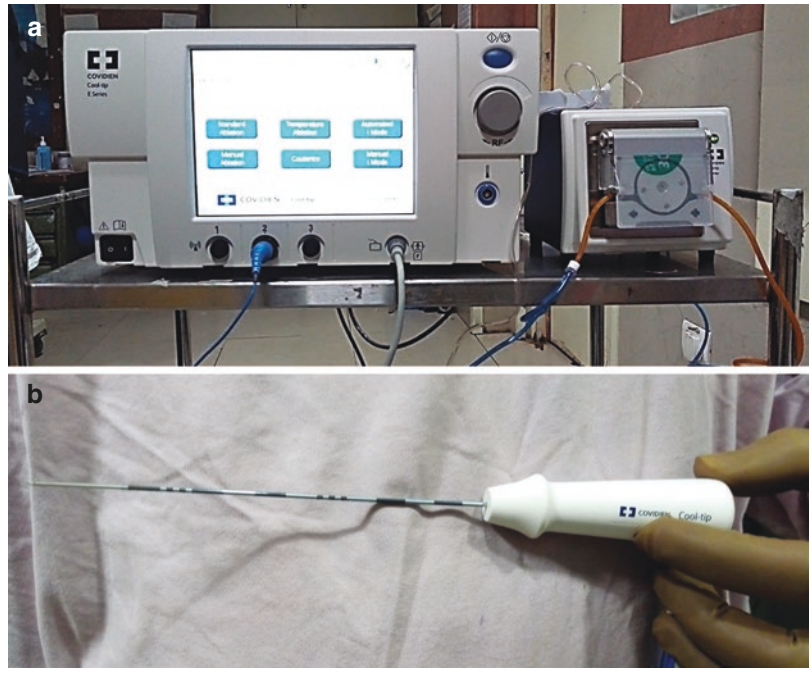

Fig. 11.1 Radiofrequency ablation equipment: (**a**) Generator and (**b**) Electrode

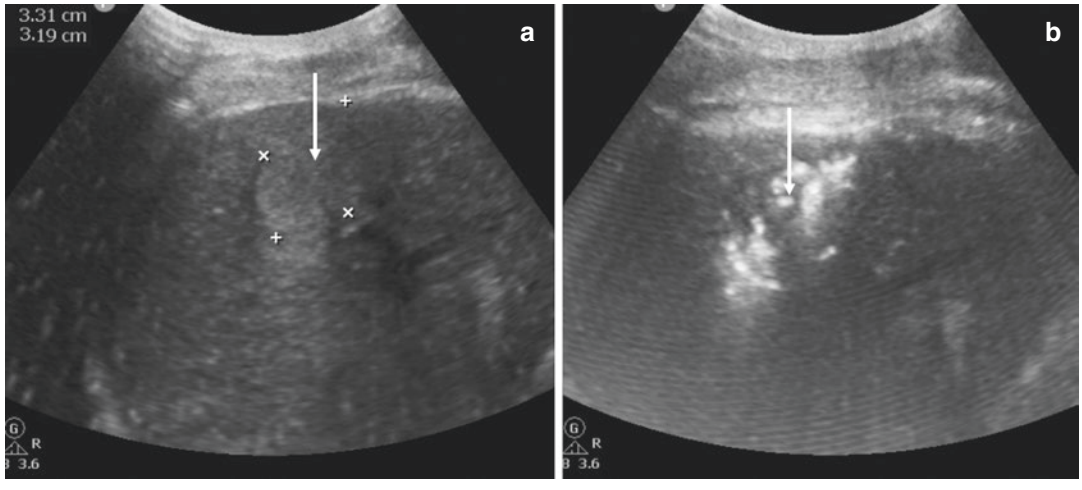

Fig. 11.2 A 58-year-old male with HCC in segment 5 treated with radiofrequency ablation. (**a**) Ultrasound image shows the lesion prior to ablation (arrow). (**b**) Ultrasound image during the procedure shows intralesional echogenicity from the tissue burning

Minneapolis, MN, USA). This type of electrode has a 17-G insulated, hollow, needle with an exposed tip of variable length. The shaft has two internal channels for chilled water perfusion. Finally, there is a separable clustered electrode (Octopus®; STARmed, Goyang, Korea). In the Octopus®, RF energy is switched between a pair of electrodes. This can create a large ablation zone in shorter time.

11.6 Endobiliary (Intraductal) RFA

11.6.1 RFA Device and Power Settings (Fig. 11.3)

Intraductal RFA catheter (HabibTM PERF catheter, EMcision Ltd) is a single-use, bipolar device [4]. It can be placed into the biliary tree over a 0.035-inch guide wire. It comprises an 8 F catheter with a 90-cm working length that can be inserted percutaneously. The distal end has a 5-mm leading tip. Proximal to the tip, there are two circumferential, 8-mm wide, stainless steel electrodes that are separated by 8 mm. This arrangement provides a cylindrical ablation of 25 mm length between the distal and proximal electrodes. The terminal at the proximal end is connected to a power generator.

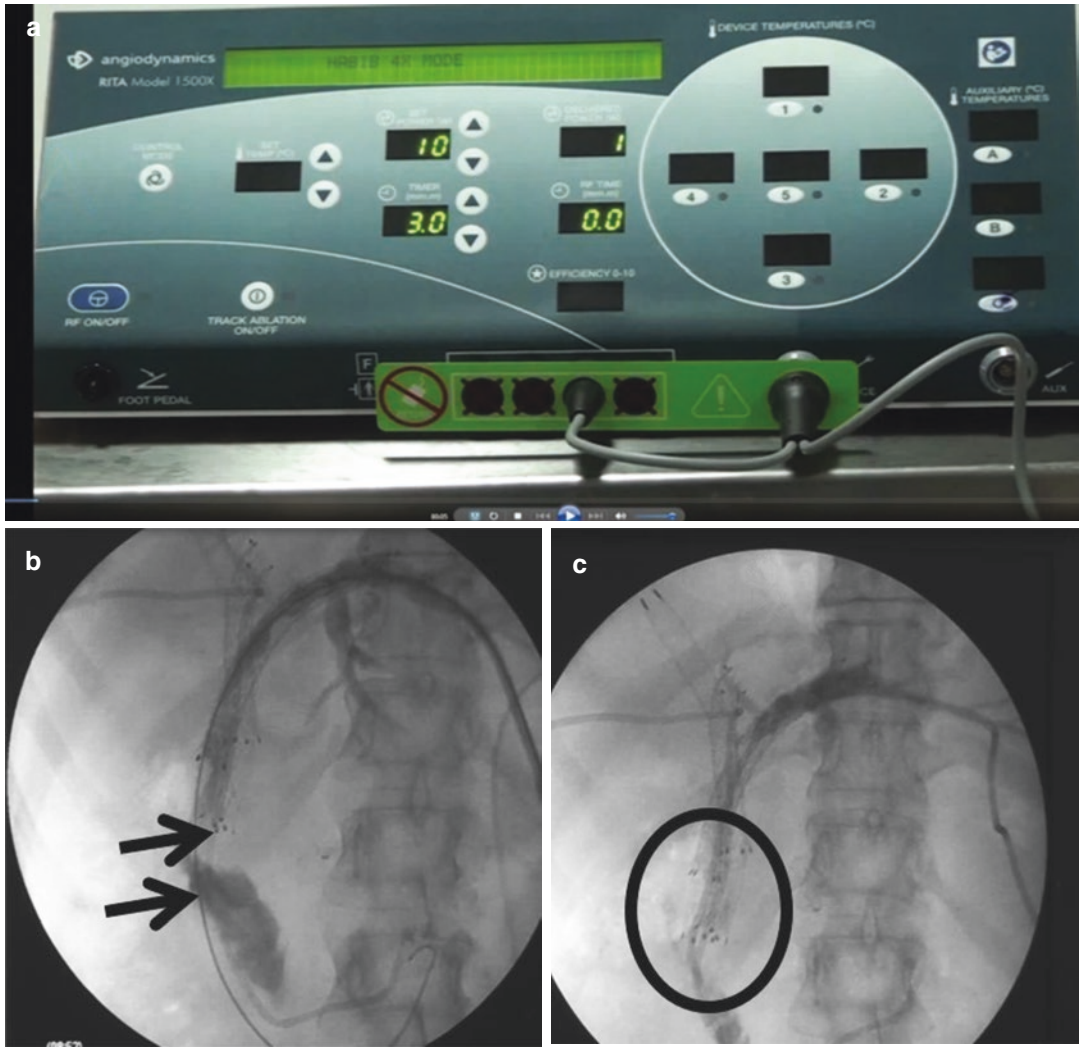

Fig. 11.3 Intraductal radiofrequency: (**a**) Generator. (**b**) Percutaneous cholangiogram shows non-opacification of the lower part of the self-expanding metallic stent (arrows). (**c**) Following the intraductal RFA, there is free flow of contrast (circle)

11.7 MWA

11.7.1 Mechanism of Ablation

Besides ionic polarization that is observed with RFA, high-frequency microwaves generate an electromagnetic field that results in rapid and homogeneous heating of tissues [13]. This action is most potent in tissues with high water content and least in fat-rich tissue.

Advantages of MWA Over RFA [12]

- Faster heating and ablation
- Higher temperature achieved
- Larger ablation zone (>5 cm)
- Lesser heat sink effect

11.7.2 Hardware (Fig. 11.4)

The device consists of three parts: generator, cable, and antenna (also called probe or applicator). MW generators are available in two frequencies: 915 MHz and 2.45 GHz [13]. MWA can be performed using single or multiple applicators. For multiple applicators, independent generators are required. The challenge while using multiple applicators is the difficulty in precise placement of multiple probes in correct relative configuration [14]. Additionally, synchronicity while performing MWA with more than one applicator results in constructive interference. Although this results in a larger ablation zone, the ablation zone is irregular. As MW generators produce different powers ranging from 45 W and 140 W at 915 MHz and 2.45GHz, different protocols are recommended based on the size of the lesion.

Fig. 11.4 Microwave ablation equipment shows generator and (probe) (arrow)

11.8 Cryoablation

11.8.1 Mechanism of Ablation

Freezing and ice formation within the extracellular space creates an osmotic gradient [15]. This causes cellular dehydration. The intracellular crystal formation causes cell membrane rupture and cell death [15]. Cooling also leads to vascular stasis and thrombosis [15]. This accelerates cell death. Cellular death by freezing requires temperatures between −20 °C and − 50 °C [16]. The cell death is further potentiated by slow thawing between the cycles of freezing. The sensitivity of tissues to freezing varies. As the connective tissue is relatively resistant, cryoablation is relatively safe for the tissues adjacent to the target lesion. Thus, cryoablation may be preferred for ablation of liver tumors near critical structures [16].

11.8.2 Hardware (Fig. 11.5)

Cryoablation commonly utilizes argon-based unit. When argon gas is circulated through the thin probe, the rapid expansion creates a very low temperature (Joule–Thompson principle) [16]. An ice ball is created around the tip of the probe. Passive slow thawing maximizes cell death. Helium gas circulated at the end of the thaw accelerates the probe removal [16]. Multiple probes can be used simultaneously to ablate larger tumors.

11.9 IRE

11.9.1 Mechanism of Ablation

IRE is a nonthermal method of ablation. Direct electric current is delivered at high voltage (up to 3000 V) and high intensity (up to 50 A) in

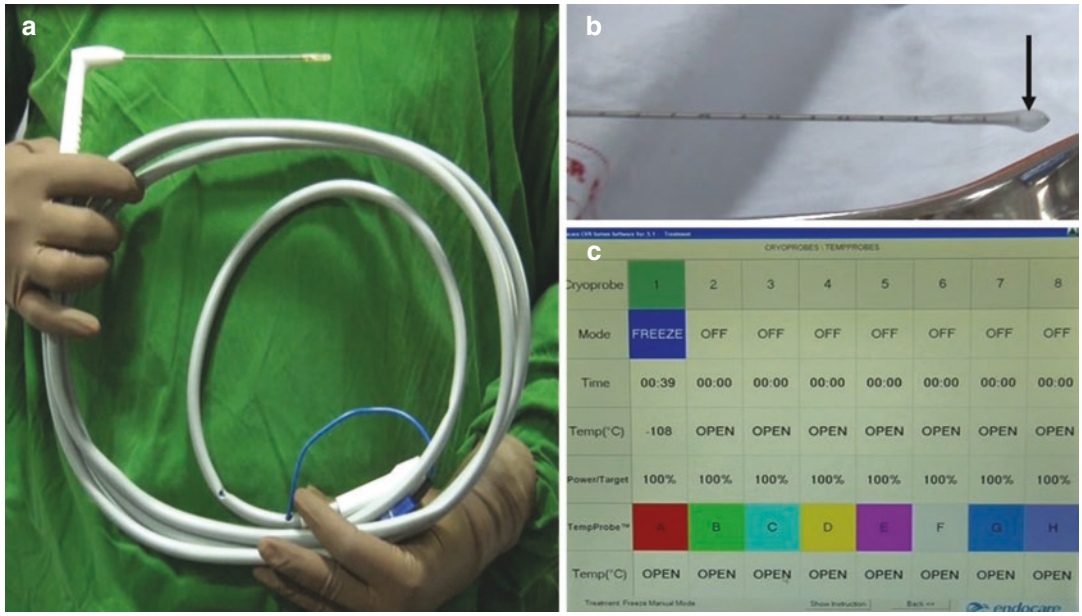

Fig. 11.5 Cryoablation equipment. (**a**) Cryoablation probe (**b**) Cryoablation probe with ice ball (arrow). (**c**) Generator settings

short pulses [17]. This leads to the formation of pores in the lipid bilayer of cell membranes and irreversible cell death [18]. The predominant pathway of cell death in IRE is apoptosis rather than coagulative necrosis which occurs in thermal ablation. Important structures in the vicinity of the target lesion like blood vessels, bile ducts, and tissue stroma are relatively resistant to IRE [19]. Due to nonthermal nature of cell damage, heat sink effect is not observed with IRE.

11.9.2 Hardware (Figs. 11.6 and 11.7)

The NanoKnife (AngioDynamics, New York) is the most commonly used commercial device. The IRE electrodes are monopolar 19 G electrodes with adjustable active tip length (5–40 mm) [19]. IRE procedures are performed under general anesthesia with muscle relaxation. The electrical pulses are delivered during the refractory phase of the myocardium (ST segment). The cardiac synchronization is achieved using a commercially available device (Accusync, Accusync Medical Research) [19].

11.10 Discussion

11.10.1 RFA Versus Surgical Resection

In an RCT by Chen et al., comparing RFA or surgical resection for solitary HCC < 5 cm, no significant difference was noted in the overall and disease-free survival rates [20]. However, in another RCT, the 1-, 3-, and 5-year overall survival and recurrence-free survival rates were significantly higher in the surgical resection group compared with the RFA group [21]. In a recent RCT comparing RFA versus resection for early HCC, 218 patients were randomized. The RFA group had a shorter treatment duration, less blood loss, and shorter hospital stay than the resection group. Mortality and morbidity rates were similar in the two groups. There was no significant difference in the overall tumor recurrence rate, 1-, 3-, 5-, and 10-year overall survival rates and corresponding disease-free survival rates [22]. A recent meta-analysis comprising five trials examining 742 patients evaluated RFA versus surgical resection for small HCC. RFA and resection had similar overall survival at 1 year whereas RFA resulted in decreased overall survival compared with resection at 5 years. The recurrence was

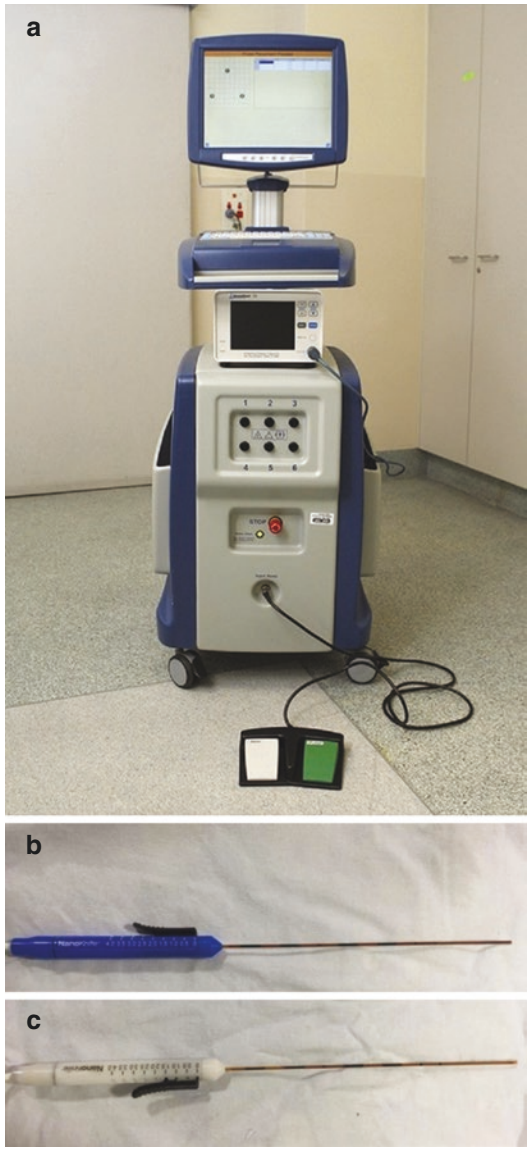

Fig. 11.6 Irreversible electroporation equipment. (**a**) Generator (**b**) Activator probe (**c**) Monopolar probe

markedly higher and the length of hospitalization significantly shorter in the RFA group compared with the resection group [23]. A recent study by Uhlig et al., compared the utilization and effectiveness RFA and surgical resection for HCC [24]. Eighteen thousand two hundred ninety-six patients from the USA National Cancer Database were included (RFA = 8211; surgical resection, n = 10,085). Duration of hospital stay and 30-day as well as 90-day mortality were lower for RFA versus surgical resection. In HCCs < 15 mm, RFA and surgical resection yielded similar survival.

11.10.2 MWA Versus Surgical Resection

In an RCT comparing MWA and resection for HCC < 5 cm, MWA group had a significantly lower complication rate. However, the local recurrences were significantly higher in the MWA group compared with the resection group. The overall recurrence and 1-, 2-, and 3-year survival rates were not significantly different between the two groups [25]. A meta-analysis by Zhang et al., suggested that MWA is as effective as resection in terms of overall survival, disease-free survival, and tumor recurrence. The advantages of MWA are shorter operation time, less amount of blood loss, and fewer complications [26]. In another recent meta-analysis by Glassberg et al. comparing MWA and resection for HCC and metastases, local tumor recurrence was significantly higher with MWA than resection [27]. Resection provided significantly higher 3- and 5-year overall survival and 3-year disease-free survival compared with MWA.

11.10.3 RFA Versus MWA

In a recent RCT comparing RFA and MWA for HCC (up to 3 lesions <4 cm), Vietti et al., did not find any difference in the local tumor progression [28]. In the study by Shibata et al., there was no statistically significant difference in the effectiveness of the two procedures [29]. In another study by Yin et al. comparing the efficacy of RFA and MWA in HCC > 3 cm, both RFA and MWA were found to be effective [30]. In a recent propensity score analysis comparing RFA and MWA for HCC within Milan criteria, RFA was found to be inferior to MWA. However, RFA had a comparable efficacy and safety for solitary HCC < 3 cm [31]. A recent meta-analysis by Tan et al. comprising 14 studies (including 4 RCTs) showed that percutaneous MWA had similar therapeutic

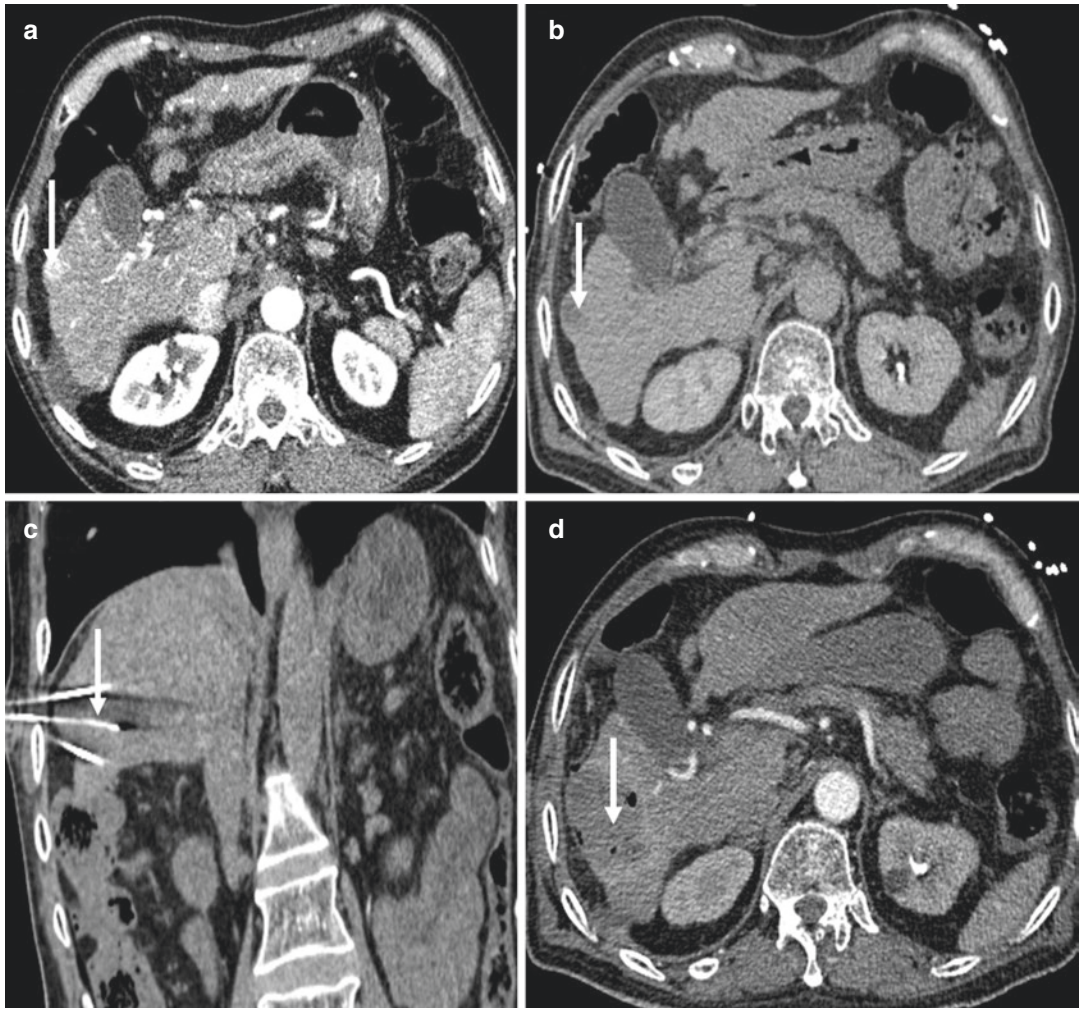

Fig. 11.7 Irreversible electroporation in a 52-year-old male with subcapsular HCC. (**a**) Arterial phase CT image shows hyperenhancing lesion in segment 5 (arrow). (**b**) There is washout in the delayed image (arrow). (**c**) Three probes are placed (arrow). (**d**) Following the procedure, there is complete ablation of the lesion

effects compared with RFA [32]. Laparoscopic MWA led to a lower local recurrence rate. The authors suggested that the superiority of MWA over RFA remains unclear.

11.10.4 RFA Versus Cryoablation

In a RCT, Wang et al. compared RFA and cryoablation for HCC < 4 cm [33]. Three-year tumor progression rate for cryoablation was lower than that of RFA. The major complications rates were comparable. In a meta-analysis comparing RFA and cryoablation for hepatic malignancies, seven studies were included [34]. There were no significant differences in mortality and local tumor progression rates. The risk of complications was significantly higher in the cryoablation group.

There are no published studies comparing MWA and cryoablation, to the best of our knowledge. Similarly, there are no human studies comparing IRE with other ablative methods.

In a recent study evaluating the long-term outcomes of percutaneous image-guided cryoablation of 299 liver tumors, Glazer et al. reported a technical success rate of 94.6% [35].

The therapeutic efficacy was 89.5% and was greatest for tumors less than 4 cm. In another study by Littrup et al., the long-term experience with percutaneous cryoablation of 443 primary and metastatic liver tumors was reported [36]. After a mean follow-up of 1.8 years, local tumor recurrence rates were 5.5% for HCC and 11.1% for CRC. There was no significant difference for local tumor recurrence rates near major blood vessels or tumors greater than 3 cm in diameter.

There had been a concern regarding the safety profile of cryoablation. This stems from the reported cases of severe bleeding, liver fractures, and cryoshock that were reported when open cryosurgery was performed. This was due to large size of the probes (up to 9 mm) [37]. However, recent studies report that cryoablation is relatively safe and is in fact the preferred method for tumors adjacent to critical structures [38]. In a study by Kim et al., comprising 28 subcapsular HCCs adjacent to the diaphragm, abdominal wall, gallbladder, colon, among other structures, the major complication was encountered only in one patient [39]. Minor complications occurred in 17.9% of cases. In another study evaluating the incidence and clinical sequelae of hepatic and portal venous thrombosis following percutaneous cryoablation in 223 liver tumors, venous thrombosis was reported in 24% of the ablations, most commonly involving the subsegmental portal vein branches [40]. None of the cases had involvement of the main portal vein or inferior vena cava. The thrombi resolved in 59% of the cases on follow-up imaging. Similar results were reported in the recent study by Kim et al. [39]. In the large US series, hematological complications were reported in 5.8% cases and were related to pre-procedural anemia/thrombocytopenia, and large tumor volumes [41]. However, no biliary leaks, strictures, or bilomas were reported on long-term follow-up.

IRE has been reported to be a safe and effective treatment for tumors in locations where thermal ablation cannot be performed due to risks to the vital structures. Kalra et al. reported the safety and efficacy of IRE in 21 unresectable HCCs [19]. Technical success was reported in all the patients. The median time to local recurrence and local tumor progression-free survival were 4 months (range 3–4 months) and 7 months (range 3–30 months), respectively during a median follow-up period of 10 months. Sutter et al. reported IRE results in 58 patients with 75 HCCs [42]. Technical success was reported in all cases. A complete ablation was achieved in 77.3% and 89.3% cases after one and two sessions of IRE, respectively. The 6-month and 12-month local tumor progression-free survival was 87% and 70%, respectively.

IRE is a relatively safe procedure. No major complications were reported in the study by Kalra et al. [19]. Sutter et al. reported major complications in three patients, however, two of these patients had poor liver function at the time of procedure [42]. Although, theoretically, IRE has no effect on the major vascular and biliary structures, Distelmaier et al. reported mild to moderate cholestasis, in 24% patients in a study [43]. This was believed to be due to the damage to the bile ducts by local heating.

11.10.5 Percutaneous Intraductal RFA

It is used as an adjunctive therapy in the management of malignant biliary strictures when endoscopic route is not feasible [4]. The aim is to prolong the patency of self-expanding metal stent (SEMS). Percutaneous RFA has also been applied to treat SEMS occlusion. The studies by Mizandari et al. and Wu et al. reported median survival and the median stent patency of 89.5 days and 84.5 days, and 181 days and 149 days respectively [44]. In their study, Wu et al. reported prolongation of stent patency and improve functional status and quality of life in patients treated with endobiliary RFA compared with the control group [45]. In the study by Acu et al., 30-day and 180-day cumulative stent patency rates were 75% and 34%, respectively, following endobiliary RFA [46]. Intraductal RFA has also been utilized to recanalize occluded SEMS [6, 47, 48].

11.11 Conclusion

Image-guided percutaneous ablative therapies play an integral role in the management of HCC. The efficacy and safety of different ablative methods have been established by RCTs. The different mechanisms of action of the ablation techniques allow their preferential case-based utilization. Ablation also plays an important role in the management of liver metastases. There is an evolving role of percutaneous intraductal RFA in the palliation of patients with malignant biliary obstruction.

References

1. Foltz G. Image-guided percutaneous ablation of hepatic malignancies. Semin Intervent Radiol. 2014;31:180–6.
2. Llovet JM, Fuster J, Bruix J. Barcelona-Clínic liver cancer group. The Barcelona approach: diagnosis, staging, and treatment of hepatocellular carcinoma. Liver Transpl. 2004;10(2, Suppl 1):S115–20.
3. Kim KH, Yoon YS, Yu CS, et al. Comparative analysis of radiofrequency ablation and surgical resection for colorectal liver metastases. J Korean Surg Soc. 2011;81:25–34.
4. Rustagi T, Jamidar PA. Intraductal radiofrequency ablation for management of malignant biliary obstruction. Dig Dis Sci. 2014;59:2635–41.
5. McDermott S, Gervais DA. Radiofrequency ablation of liver tumors. Semin Intervent Radiol. 2013;30:49–55.
6. Mukund A, Arora A, Rajesh S, Bothra P, Patidar Y. Endobiliary radiofrequency ablation for reopening of occluded biliary stents: a promising technique. J Vasc Interv Radiol. 2013;24:14244.
7. Gurney JM, Lee FT Jr, Cha C, Markhardt BK, Mahvi DM, Warner TF. CT vs ultrasound (US) for guidance of radiofrequency (RF) ablation in a porcine liver model: radiologic-pathologic correlation (abstr). Radiology. 1999;213(P):123.
8. Jungraithmayr W, Burger D, Olschewski M, Eggstein S. Cryoablation of malignant liver tumors: results of a single center study. Hepatobiliary Pancreat Dis Int. 2005;4:554–60.
9. Raman SS, Aziz D, Chang X, Sayre J, Lassman C, Lu D. Minimizing diaphragmatic injury during radiofrequency ablation: efficacy of intraabdominal carbon dioxide insufflation. AJR Am J Roentgenol. 2004;183:197–200.
10. Gupta P, Kalra N, Keshava SN, et al. Indian Society of Vascular and Interventional Radiology Expert Consensus Statements for Ablation in Hepatocellular Carcinoma: Part I. JCIR ISVIR 2020. https://doi.org/10.1055/s-0040-1715774 (Ahead of Print)
11. Goldberg SN, Gazelle GS, Mueller PR. Thermal ablation therapy for focal malignancy: a unified approach to underlying principles, techniques, and diagnostic imaging guidance. Am J Roentgenol. 2000;174:323–31.
12. Kalra N, Gupta P, Chawla Y, Khandelwal N. Locoregional treatment for hepatocellular carcinoma: the best is yet to come. World J Radiol. 2015;7:306–18.
13. Vogl TJ, Nour-Eldin NA, Hammerstingl RM, Panahi B, Naguib NNN. Microwave ablation (MWA): basics, technique and results in primary and metastatic liver neoplasms - review article. Rofo. 2017;189:1055–66.
14. Yu NC, Lu DS, Raman SS, et al. Hepatocellular carcinoma: microwave ablation with multiple straight and loop antenna clusters – pilot comparison with pathologic findings. Radiology. 2006;239:269–75.
15. Silverman SG, Tuncali K, van Sonnenberg E, et al. Renal tumors: MR imaging-guided percutaneous cryotherapy--initial experience in 23 patients. Radiology. 2005;236:716–24.
16. Tatli S, Acar M, Tuncali K, Morrison PR, Silverman S. Percutaneous cryoablation techniques and clinical applications. Diagn Interv Radiol. 2010;16:90–5.
17. Charpentier KP. Irreversible electroporation for the ablation of liver tumors: are we there yet? Arch Surg. 2012;147:1053–61.
18. Cannon R, Ellis S, Hayes D, Narayanan G, Martin RC II. Safety and early efficacy of irreversible electroporation for hepatic tumors in proximity to vital structures. J Surg Oncol. 2013;107:544–9.
19. Kalra N, Gupta P, Gorsi U, et al. Irreversible electroporation for Unresectable hepatocellular carcinoma: initial experience. Cardiovasc Intervent Radiol. 2019;42:584–90.
20. Chen MS, Li JQ, Zheng Y, et al. A prospective randomized trial comparing percutaneous local ablative therapy and partial hepatectomy for small hepatocellular carcinoma. Ann Surg. 2006;243:321–8.
21. Feng Q, Chi Y, Liu Y, Zhang L, Liu Q. Efficacy and safety of percutaneous radiofrequency ablation versus surgical resection for small hepatocellular carcinoma: a meta-analysis of 23 studies. J Cancer Res Clin Oncol. 2015;141:1–9.
22. Ng KKC, Chok KSH, Chan ACY, et al. Randomized clinical trial of hepatic resection versus radiofrequency ablation for early-stage hepatocellular carcinoma. Br J Surg. 2017;104:1775–84.
23. Xu XL, Liu XD, Liang M, Luo BM. Radiofrequency ablation versus hepatic resection for small hepatocellular carcinoma: systematic review of randomized controlled trials with meta-analysis and trial sequential analysis. Radiology. 2018;287:461–72.
24. Uhlig J, Sellers CM, Stein SM, Kim HS. Radiofrequency ablation versus surgical resection of hepatocellular carcinoma: contemporary treatment

trends and outcomes from the United States National Cancer Database. Eur Radiol. 2019;29:2679–89.
25. Xu J, Zhao Y. Comparison of percutaneous microwave ablation and laparoscopic resection in the prognosis of liver cancer. Int J Clin Exp Pathol. 2015;8:11665–9. eCollection 2015
26. Zhang M, Ma H, Zhang J, He L, Ye X, Li X. Comparison of microwave ablation and hepatic resection for hepatocellular carcinoma: a meta-analysis. Onco Targets Ther. 2017;10:4829–39.
27. Glassberg MB, Ghosh S, Clymer JW, Wright GWJ, Ferko N, Amaral JF. Microwave ablation compared with hepatic resection for the treatment of hepatocellular carcinoma and liver metastases: a systematic review and meta-analysis. World J Surg Oncol. 2019;17:98.
28. Vietti Violi N, Duran R, Guiu B, et al. Efficacy of microwave ablation versus radiofrequency ablation for the treatment of hepatocellular carcinoma in patients with chronic liver disease: a randomised controlled phase 2 trial. Lancet Gastroenterol Hepatol. 2018;3:317–25.
29. Shibata T, Iimuro Y, Yamamoto Y, et al. Small hepatocellular carcinoma: comparison of radio-frequency ablation and percutaneous microwave coagulation therapy. Radiology. 2002;223:331–7.
30. Yin XY, Xie XY, Lu MD, et al. Percutaneous thermal ablation of medium and large hepatocellular carcinoma: long-term outcome and prognostic factors. Cancer. 2009 May 1;115(9):1914–23.
31. Liu W, Zheng Y, He W, et al. Microwave vs radiofrequency ablation for hepatocellular carcinoma within the Milan criteria: a propensity score analysis. Aliment Pharmacol Ther. 2018;48:671–81.
32. Tan W, Deng Q, Lin S, Wang Y, Xu G. Comparison of microwave ablation and radiofrequency ablation for hepatocellular carcinoma: a systematic review and meta-analysis. Int J Hyperth. 2019;36:264–72.
33. Wang C, Wang H, Yang W, et al. Multicenter randomized controlled trial of percutaneous cryoablation versus radiofrequency ablation in hepatocellular carcinoma. Hepatology. 2015;61:1579–90.
34. Wu S, Hou J, Ding Y, et al. Cryoablation versus radiofrequency ablation for hepatic malignancies: a systematic review and literature-based analysis. Medicine (Baltimore). 2015;94:e2252.
35. Glazer DI, Tatli S, Shyn PB, Vangel MG, Tuncali K, Silverman SG. Percutaneous image-guided Cryoablation of hepatic tumors: single-center experience with intermediate to long-term outcomes. AJR Am J Roentgenol. 2017;209:1381–9.
36. Littrup PJ, Aoun HD, Adam B, Krycia M, Prus M, Shields A. Percutaneous cryoablation of hepatic tumors: long-term experience of a large U.S. series. Abdom Radiol (NY). 2016;41:767–80.
37. Sarantou T, Bilchik A, Ramming KP. Complications of hepatic cryosurgery. Semin Surg Oncol. 1998;14:156–62.
38. Ravikumar TS, Kane R, Cady B, et al. Hepatic cryosurgery with intraoperative ultrasound monitoring for metastatic colon carcinoma. Arch Surg. 1987;122:403–9.
39. Kim GM, Won JY, Kim MD, et al. Cryoablation of hepatocellular carcinoma with high-risk for percutaneous ablation: safety and efficacy. Cardiovasc Intervent Radiol. 2016;39:1447–54.
40. Sainani NI, Silverman SG, Tuna IS, et al. Incidence and clinical sequelae of portal and hepatic venous thrombosis following percutaneous cryoablation of liver tumors. Abdom Radiol (NY). 2016;41:970–7.
41. Kim R, Kang TW, Cha DI, et al. Percutaneous cryoablation for perivascular hepatocellular carcinoma: therapeutic efficacy and vascular complications. Eur Radiol. 2019;29:654–62.
42. Sutter O, Calvo J, N'Kontchou G, et al. Safety and efficacy of irreversible electroporation for the treatment of hepatocellular carcinoma not amenable to thermal ablation techniques: a retrospective single-center case series. Radiology. 2017;284:877–86.
43. Distelmaier M, Barabasch A, Heil P, et al. Midterm safety and efficacy of irreversible electroporation of malignant liver tumors located close to major portal or hepatic veins. Radiology. 2017;285:1023–31.
44. Mizandari M, Pai M, Xi F, et al. Percutaneous intraductal radiofrequency ablation is a safe treatment for malignant biliary obstruction: feasibility and early results. Cardiovasc Intervent Radiol. 2013;36:814–9.
45. Wu TT, Li HC, Li WM, et al. Percutaneous intraluminal radiofrequency ablation for malignant extrahepatic biliary obstruction: a safe and feasible method. Dig Dis Sci. 2015;60:2158–63.
46. Acu B, Kurtulus OE. Feasibility and safety of percutaneous transhepatic endobiliary radiofrequency ablation as an adjunct to biliary stenting in malignant biliary obstruction. Diagn Interv Imaging. 2018;99:237–45.
47. Pai M, Valek V, Tomas A, et al. Percutaneous intraductal radiofrequency ablation for clearance of occluded metal stent in malignant biliary obstruction: feasibility and early results. Cardiovasc Intervent Radiol. 2014;37:235–40.
48. Duan XH, Wang YL, Han XW, et al. Intraductal radiofrequency ablation followed by locoregional tumor treatments for treating occluded biliary stents in non-resectable malignant biliary obstruction: A single-institution experience. PLoS One. 2015;10:e0134857.

12 Transarterial Therapies for Benign and Malignant Liver Tumors

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12.1 Introduction

Liver tumors are growths on or in the liver. The names of tumors associated with the liver usually start with "hepato" or "hepatic," originating from the Greek word *hepar,* meaning liver.

There are several distinct types of tumors which develop from various cell types of the liver and classified as benign or malignant tumors.

- Benign tumors, namely hemangioma, hemangioendothelioma, focal nodular hyperplasia, and hepatic adenoma.
- Malignant tumors include primary tumors like hepatocellular carcinoma, hepatoblastoma, cholangiocarcinoma, or metastasis from various other tumors.

Metastatic deposit is the most common hepatic tumor, while hepatocellular carcinoma is the most common primary hepatic malignancy [1]. Most patients with liver tumors present late with tumor burden and underlying hepatic disease not feasible for curative resection or transplant or due to the presence of non-hepatic comorbid conditions [1]. Even if the tumor completely resected with adequate tumor-free resection margins, the recurrence rate is up to 50 percent within 2 years of surgery [1].

The principle of transarterial liver-directed therapies revolves around the basic concept of dual blood supply of the normal liver. The carcinogenesis of hepatic neoplasm is a multistep process involving parenchymal arterialization, sinusoidal capillarization, and neo-angiogenesis, with 90% of the blood supply to liver tumors arising from the hepatic artery [2]. As such, an agent infused via the hepatic artery attains ten times higher intra-tumoral concentration as compared to when given via the portal vein relatively sparing the healthy liver parenchyma [3]. Embolization induces ischemic necrosis of the tumor, causing a failure of the transmembrane pump, resulting in more excellent absorption of agents by the tumor cells [4].

12.2 Anatomy of Hepatic Artery

The common hepatic artery usually arises from the coeliac artery. It gives rise to the proper hepatic artery, which further divides into the right and left hepatic arteries to supply the entire liver. However, such classical arterial branching may be present in only 55–60% (Fig. 12.1). In comparison, there are variations in 40–45% of the population, and Michel et al. suggested a classification system depending on the branching patterns [5].

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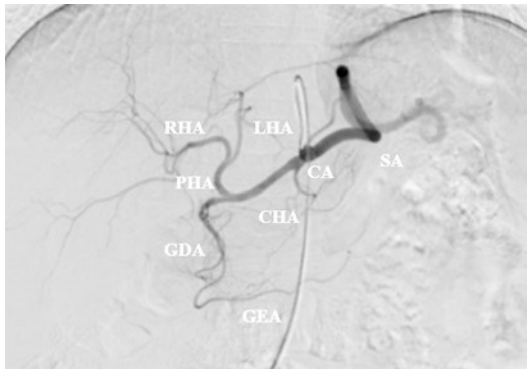

Fig. 12.1 Normal hepatic arterial anatomy arising from the coeliac axis. Abbreviations: *CA* coeliac artery, *CHA* common hepatic artery, *PHA* proper hepatic artery, *GDA* gastroduodenal artery, *RHA* right hepatic artery, *LHA* left hepatic artery, *SMA* superior mesenteric artery, *SA* splenic artery

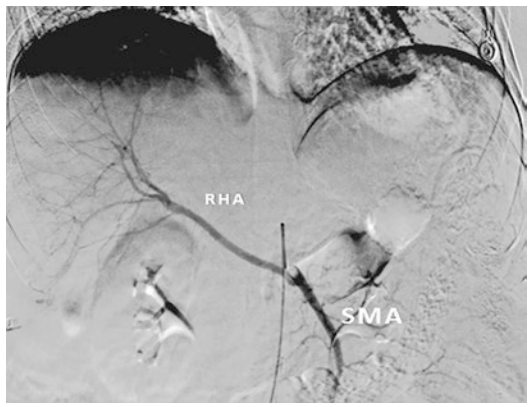

Fig. 12.2 Replaced Right hepatic artery arising from the superior mesenteric artery

The conventional variants are replaced right hepatic artery arising from the superior mesenteric artery (Fig. 12.2), a replaced left hepatic artery arising from the left gastric artery or direct origin of the right hepatic artery from the aorta (Fig. 12.3).

Often, larger tumors in the liver recruit blood supply from extrahepatic vasculature, and evaluation of these arterial supply in subsequent sessions of chemoembolization is essential for complete treatment (Figs. 12.4, 12.5, and 12.6). As such, in cases of persistent neoplastic tissue, all the possible branches to extrahepatic structures and possible extrahepatic collaterals supplying liver tumors must be also be identified [6].

The commonly used catheters to access the feeding arteries are 4F SIM 1, Cobra, SOS, or Shepherd Hook. Using a 2.9F or smaller sized microcatheter like Progreat, Headway, or Rebar, the tumor supplying artery is super selectively cannulated to treat only the tumor and minimize the exposure to normal liver parenchyma.

12.3 Transarterial Catheter-Directed Therapies

Transarterial liver therapies include mainly

- Transarterial (Hepatic) artery embolization (TAE) or bland embolization
- Conventional Transarterial chemoembolization (cTACE) using lipiodol
- Transarterial chemoembolization using drug-eluting beads (DEB-TACE)
- Transarterial radioembolization (TARE) / Selective intra-arterial radiotherapy (SIRT) using yttrium-90 (Y-90)

12.3.1 Transarterial (Hepatic) Artery Embolization (TAE) or Bland Embolization

The goal of TAE is tumor ischemia via terminal arterial obstruction using particles. Bland embolization is done mostly in the case of a patient presenting with a ruptured hepatic tumor to control hemoperitoneum (Figs. 12.7 and 12.8), embolization of symptomatic benign tumors like hepatic adenoma, giant hemangioma and low-grade malignant tumors like neuroendocrine tumors. Polyvinyl alcohol particles (PVA), which are small and irregular flakes of polyvinyl alcohol or gelatin sponge suspension made by grating minute flakes of gel foam, are respectively used for occlusion of the tumoral bed.

12.3.2 Transarterial Chemoembolization

TACE treatment combines targeted delivery of antineoplastic agents and embolization of the tumor arterial supply. The infusion of antineo-

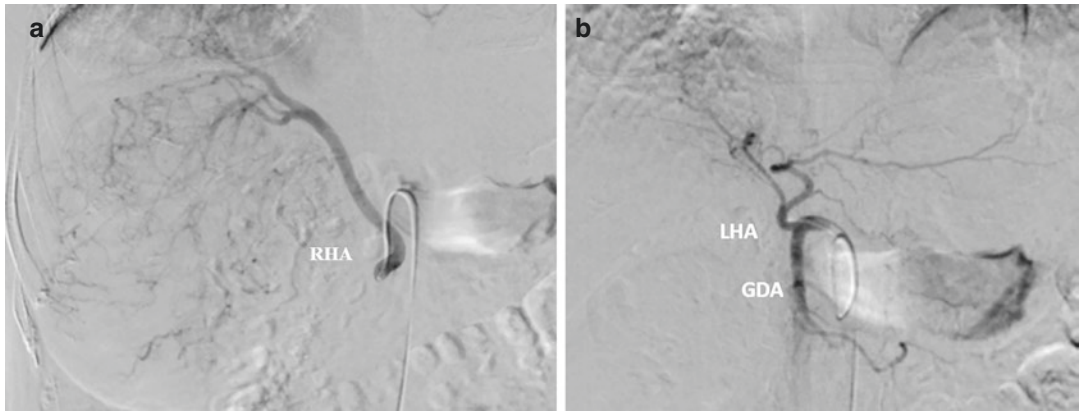

Fig. 12.3 (**a**, **b**) Right Hepatic artery arising from the aorta with Left hepatic artery from the coeliac trunk

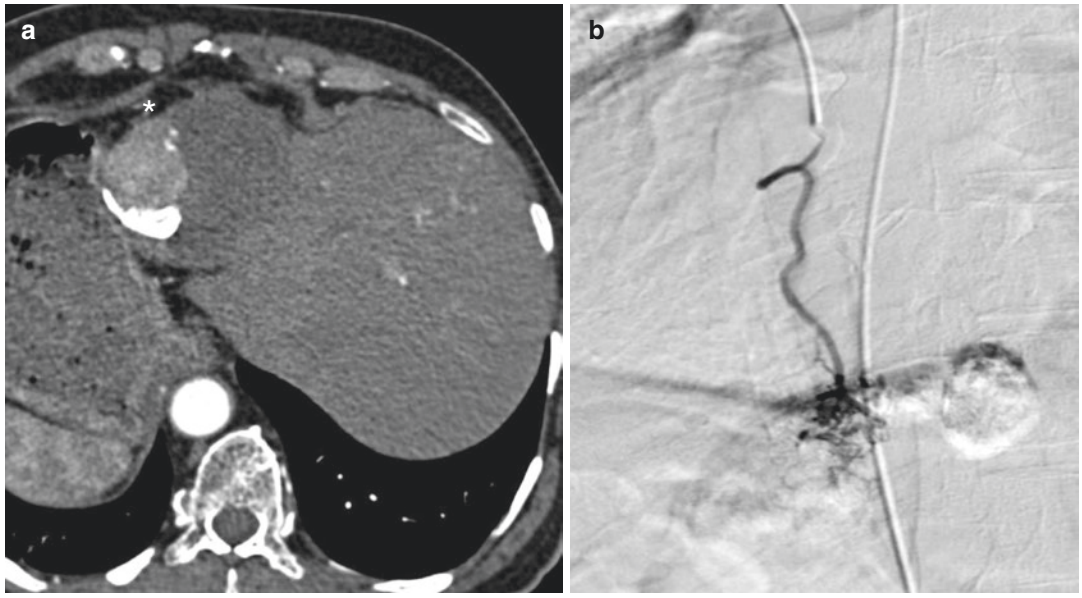

Fig. 12.4 (**a**) A 75-year-old HbsAg positive case of HCC, with situs inversus, post-three sessions of TACE, CT scan shows residual enhancement [*]. (**b**) Extrahepatic supply from the right internal mammary artery was seen and embolised

plastic drugs results in the delivery of a high concentration of chemotherapy to the tumor, more significant compared to the intravenous route. Also, the arterial route of injecting chemotherapy results in fewer systemic side effects, and embolization causes devascularization of the tumor. Hence, the tumoricidal result of TACE is both due to antineoplastic drug and ischemia. TACE may be cTACE or DEB-TACE and their techniques followed in our institute are detailed below.

1. Conventional Transarterial Chemoembolization (cTACE).

   cTACE is the most commonly performed transarterial therapy and is used primarily in

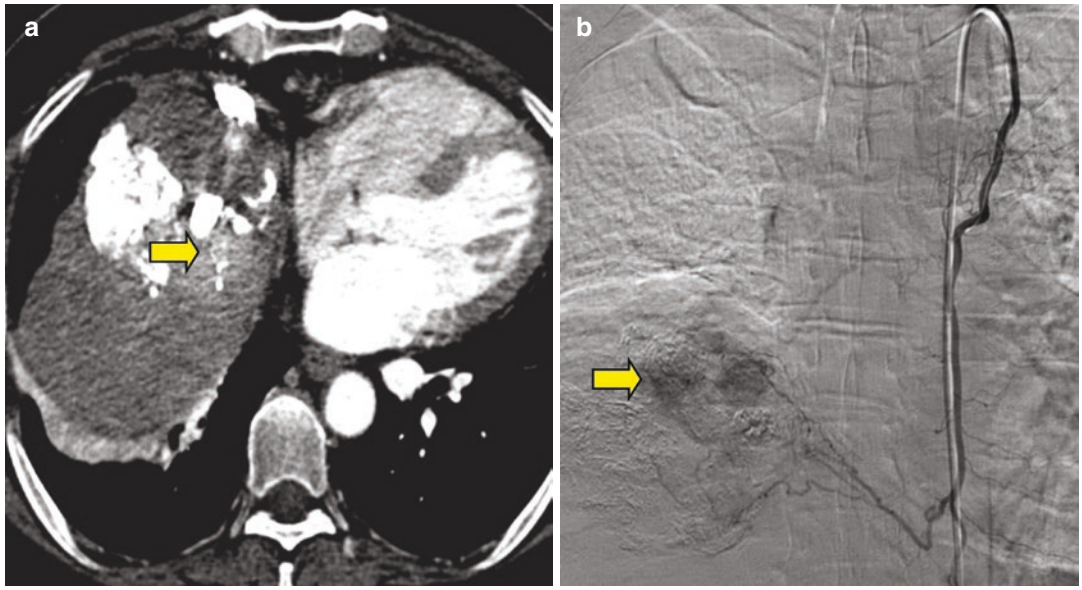

Fig. 12.5 (**a**) 59-year-old case of HCC. Large tumor in segment IV A, VIII, post-four sessions of TACE. (**b**) Extrahepatic supply from left internal mammary arteries (yellow arrows showing enhancement)

cases of multiple liver lesions. It may be used in combination with ablation, the secondary intention being to coat the lesions with lipiodol to facilitate easy visibility and accessibility for ablation under fluoroscopy or computed tomography. The chemotherapy drug emulsion includes mixing of 50–75 mg doxorubicin aqueous solution with lipiodol. The ratio of the emulsion is 1:2 (in volume) of the drug in lipiodol, and the maximum amount of lipiodol should not exceed 15 ml. Preparation of emulsion includes mixing of doxorubicin solution taken in one syringe and lipiodol in another. The contents of the syringe loaded with doxorubicin is pushed into the syringe containing lipiodol using three-way stop cock, to favor a water-in-oil emulsion. The size of the emulsion droplets should be in the range of 70–100 microns for adequate deposition of the drug-lipiodol mixture in the tumor bed and is achieved by at least 20 pumping exchanges through the stopcock. The Doxorubicin/Lipiodol emulsion is injected into the tumor feeding artery with or without cisplatin as per institutional protocol (single drug or two drugs TACE). Cisplatin may be injected using sandwich technique after each aliquot of the doxorubicin-lipiodol emulsion or it may be infused slowly before starting the injection of emulsion. After injecting drug-lipiodol emulsion, embolization is performed super-selective injection of gelatin sponge (gel foam) particles or 100–300 microns PVA particles till the vascularity of the tumor disappears. The embolization endpoint should be 2 to 5 heartbeats to clear the contrast medium. A post-embolization angiogram is performed to demonstrate the preservation of vascularity of untreated liver and adjacent structures.

2. Transarterial Chemoembolization Using Drug-Eluting Beads (DEB-TACE).

DEB-TACE, as compared to cTACE, not only delivers the chemotherapeutic drug but also embolises the tumor bed while minimizing systemic side effects. Drug-Eluting Beads (DEB) is a micro-spherical embolization product composed of acrylamido polyvinyl alcohol–*co*–acrylamido-2-methylpropane sulfonate capable of loading and slowly eluting positively charged drugs such as doxorubicin or Irinotecan via an ion exchange process. Drug-eluting beads (DEB) are loaded with the chemotherapeutic drug (doxorubicin for hepatocellular carcinoma

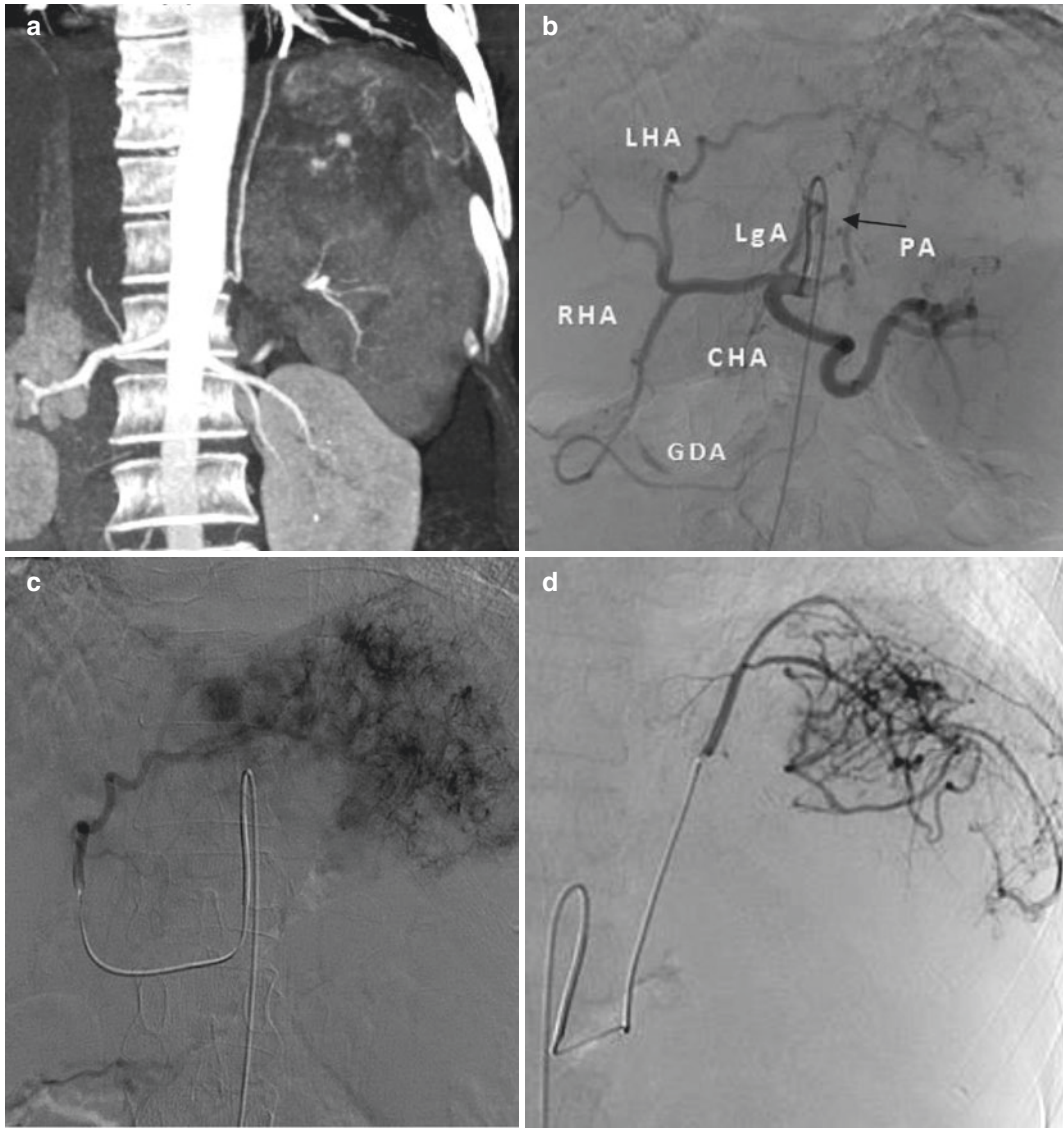

Fig. 12.6 (**a**, **b**) 76-year-old woman, HbsAg positive with a large mass in the left lobe of the liver. (**c**) Left hepatic artery and (**d**) Phrenic artery (Black arrow) seen arising from the coeliac artery and supplying the tumor. *PA* phrenic artery, *LgA* left gastric artery

and Irinotecan for colorectal liver metastases) to be released slowly in a sustained manner to ensure high local and low systemic levels of drug concentration. At present, two drug-eluting beads are commercially available in the Indian market; DC beads (Biocompatibles UK Limited, BTG International group company Farnham, UK) and Hepasphere (Biosphere, Merit) and loading of chemotherapeutic agents should be performed as per manufacturer's instruction.

(a) Preparation of DC Beads

DC beads are available in sizes of 100–300 μ and 300–500 μ, and smaller sized beads are preferred for deeper penetration of DEB into the tumor. Saline is removed from a vial of DC Bead and loaded with 75 mg of doxorubicin in 2 ml of sterile

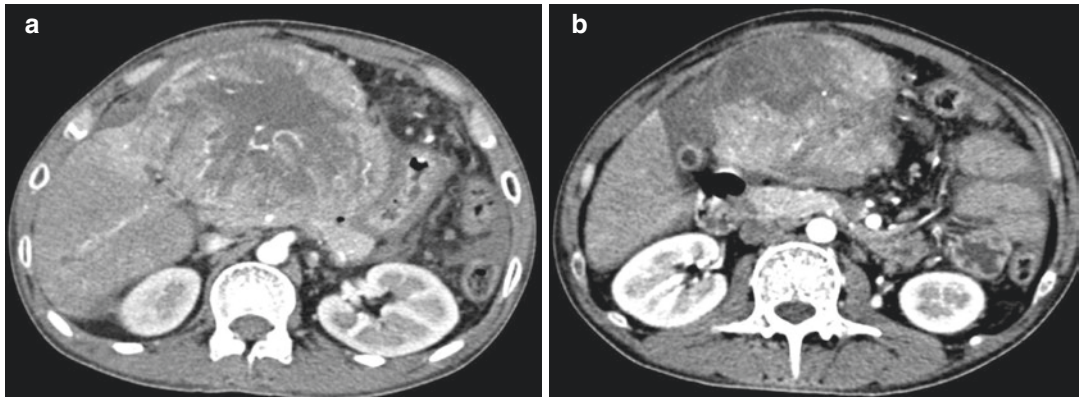

Fig. 12.7 (**a**, **b**) A 28-year-old man, known case of Hepatitis B associated HCC, presented in the casualty with hypotension and tachycardia. Triphasic CECT reveals hemoperitoneum with a ruptured tumor in segment IVb. The patient underwent emergency bland embolization to control the tumoral bleed

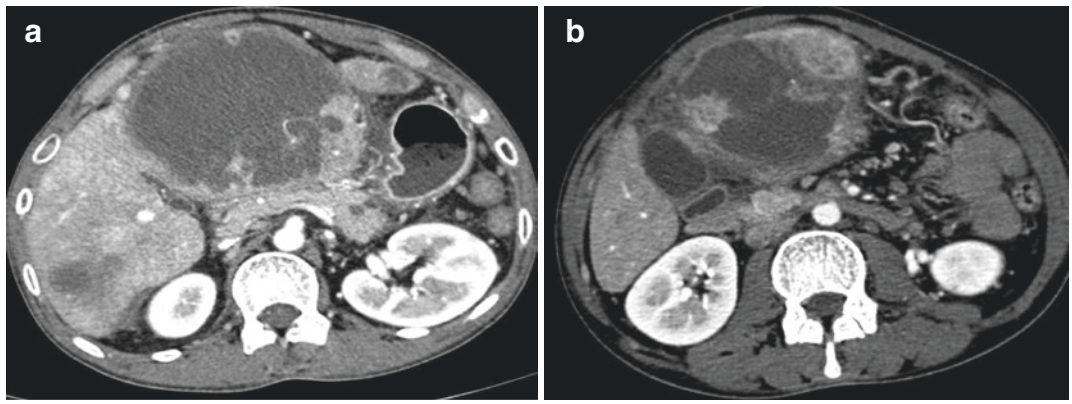

Fig. 12.8 (**a**, **b**) Two months after embolization, triphasic CECT shows partial necrosis of the tumor

water for injection or 100 mg Irinotecan depending on tumor being HCC or colorectal liver metastases respectively. Loading will take a minimum of 45 min for DEBDOX Bead and up to 120 min for DEBIRI**.** Before use, the DC Bead loaded with the drugs is transferred to a polycarbonate syringe and diluted with nonionic contrast media before infusion.

(b) Preparation of Hepasphere

Hepaspheres are available in sizes of 30–60 μ and 50–100 μ, each of which enlarges up to four times its original size after reconstitution with the chemotherapeutic drugs after the period of loading. 75 mg of lyophilized doxorubicin HCl in 20 ml of NaCl 0.9% solution (for HCC) or 100 mg Irinotecan (for colorectal liver metastases) may be loaded into the vial of HepaSphere Microspheres. A minimum loading time of 30 min with intermittent shaking is required. At least 20–30 mL of nonionic contrast medium is added to drug-loaded HepaSphere Microspheres to have better control during embolization.

12.3.3 Transarterial Radioembolization (TARE)/ Selective Intra-Arterial Radiotherapy (SIRT) Using Yttrium-90

Radioembolization's mechanism of action is the delivery of internal radiation to liver tumors without significant embolic phenomenon. Transarterial therapies have evolved as effective and widely used palliative treatment options for unresectable hepatic tumors. In some instances, it has been used to down-

stage the tumor for surgery. TARE is selective intra-arterial administration of microspheres loaded with pure beta emitters such as Yttrium 90 or lipiodol labeled with iodine or rhenium and has no or minimal ischemic effects. Y-90 is the most common isotope used for radioembolization. It is a beta emitter that has a half-life of 64.2 h and a penetration of 2.5 mm.

Preparatory arteriography is needed to assess the feasibility of radioembolization. In this pre-TARE angiography following things are analyzed

1. Hepatic arterial anatomy: The hepatic arterial branches primarily feeding the tumor should be assessed to identify an appropriate site of injection to cover the entire tumor avoiding hepatofugal arteries. The hepatofugal arteries like gastroduodenal, right gastric, supraduodenal, and falciform arteries are those which arise from the hepatic artery and supply non-hepatic sites. These arterial branches can be prophylactically embolized with coils (Fig 12.9) to increase the safety of radioembolisation.

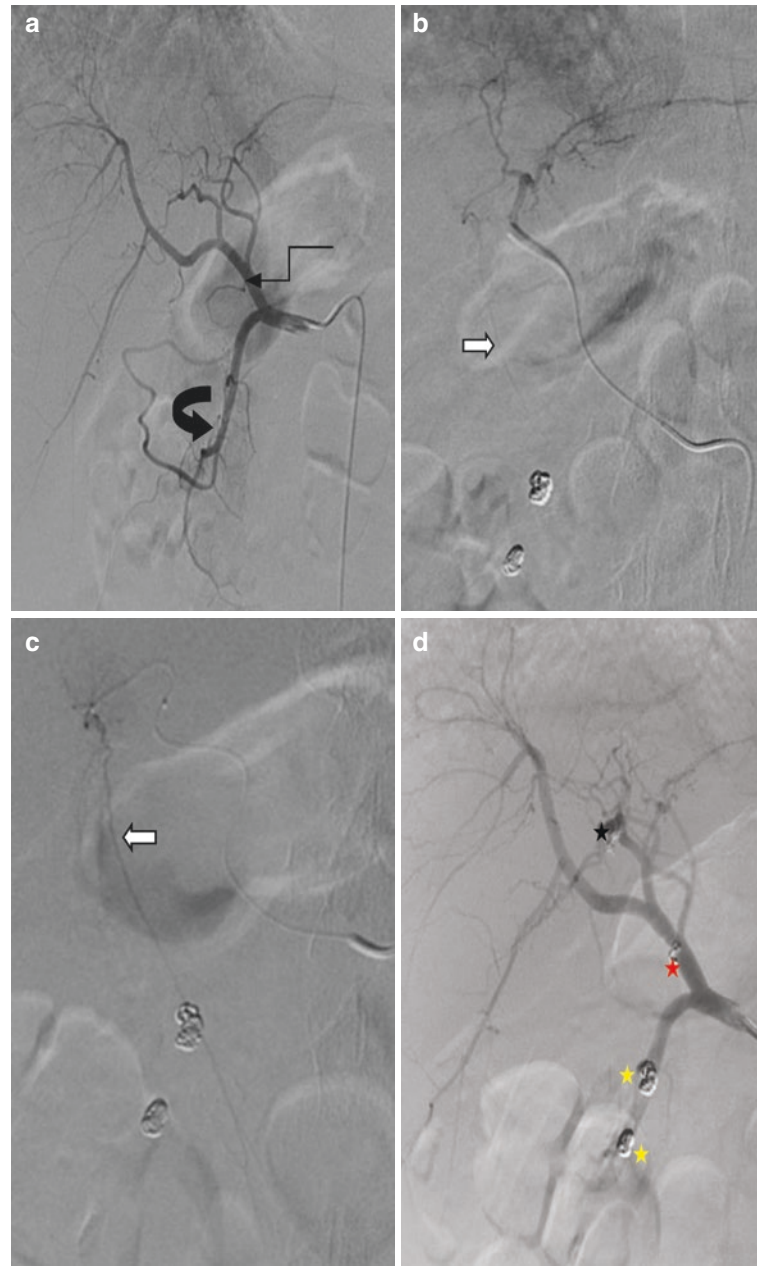

Fig. 12.9 (**a**–**d**) Coiling of non-target arteries to prevent reflux of Y90 spheres (curved arrow—gastroduodenal artery, straight arrow—right gastric artery, white block arrows—falciform artery arising from the middle hepatic artery, stars—coils)

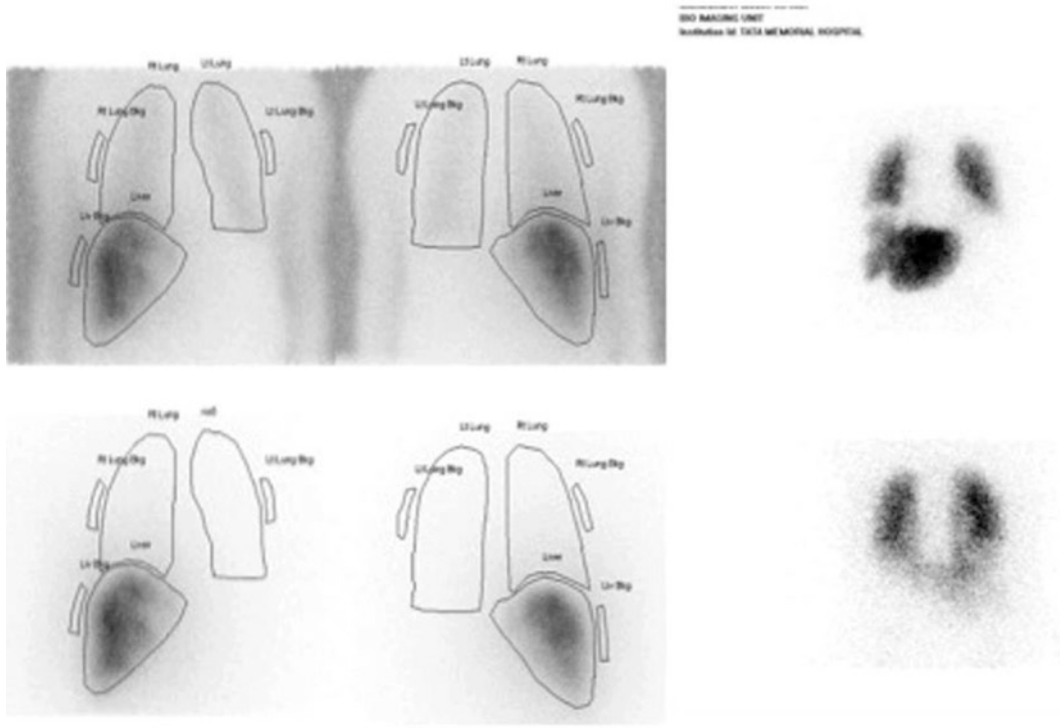

Fig. 12.10 Hepatopulmonary shunt evaluation using SPECT scan after Tc-99 labeled MAA infusion from the right hepatic artery

2. Hepatopulmonary shunt: 99mTc labeled macro aggregated albumin (99mTc-MAA) is injected at the target site. Subsequently, scintigraphy (SPECT scan) is done to ensure that there is no reflux into the gastrointestinal tract and lungs (Fig. 12.10). The hepatopulmonary shunt should be less than 30Gy per treatment session with a maximum cumulative dose of 50Gy to reduce the chances of radiation pneumonitis.
3. Tumor volumetry: Treatment planning of TARE is personalized as with all other radiotherapy treatments. The idea is to deliver an optimum therapeutic dose to the tumor while limiting the dose to the healthy liver as low as possible. For this, volumes of tumor perfusion, normal liver parenchymal perfusion, and total liver perfusion need to be calculated. At the time of pre-TARE planning, 3DCT scans are done with a catheter placed at the intended site of infusion of the radiopharmaceutical to obtain CT volumetry (Fig.12.11). The dose that needs to be injected during radioembolisation is based on tumoral perfusion volume and hepatopulmonary shunt which is calculated using the empiric formula suggested by the manufacturers to achieve a nominal tumor target dose of 120–140 Gy. There are two commercially available Y-90 medical devices currently available: TheraSphere Glass spheres (BTG International, London, United Kingdom) and SIR-Spheres Resin Microspheres (Sirtex Medical, Sydney, Australia).

During SIRT, the microspheres loaded with Y-90 are selectively delivered through a closed

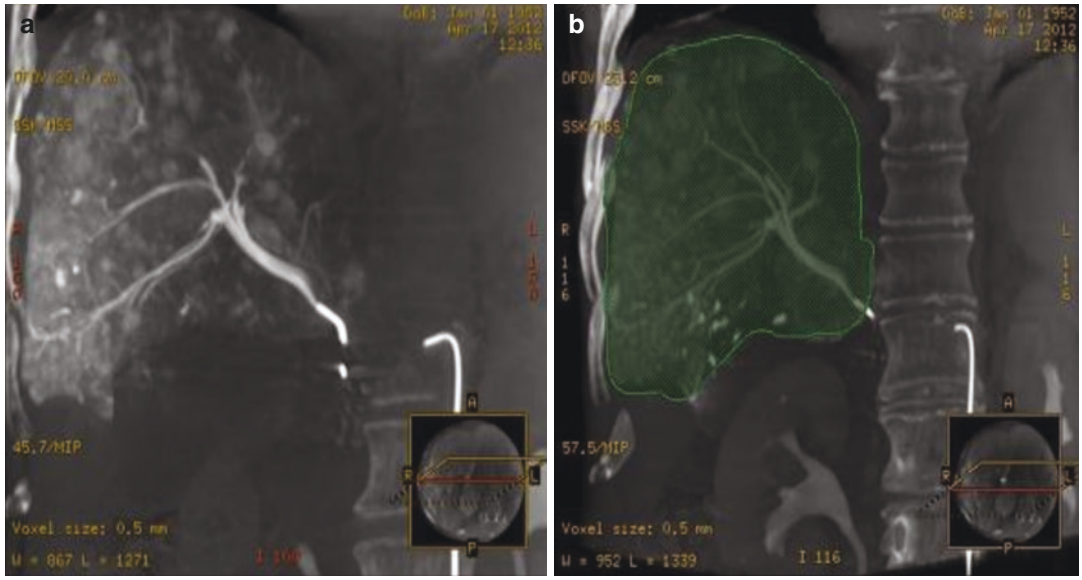

Fig. 12.11 (**a**, **b**) CT volumetric evaluation of a 60 year old, hepatitis-related multifocal HCC patient referred for TARE

delivery circuit using a proprietary delivery system specific to the particular device. Within 24 h, the patient undergoes a Y90-PET scan at the author's institute to document the deposition of the yttrium within the targeted tumor and exclude any extrahepatic deposition (Fig. 12.22).

12.4 Hepatocellular Carcinoma

12.4.1 Transarterial Chemoembolisation (TACE)

Hepatocellular carcinoma (HCC) is the most common primary liver malignancy and is the leading cause of death in patients with liver cirrhosis [7]. Barcelona Clinic Liver Cancer (BCLC) staging is one of the staging system widely used to decide the appropriate treatment for HCC (Fig. 12.12) [8]. Transarterial chemoembolization is the recommended first-line treatment for BCLC stage B patients.

TACE, when used appropriately, provides survival benefits without adversely affecting the liver function [9, 10]. It aims at obtaining cytoreduction by regional delivery of chemotherapeutic agents and ischemia by embolization of tumoral arterial feeders.

12.4.1.1 Indications

TACE is offered primarily to patients with unresectable HCC, especially those with BCLC-B (intermediate) stage.

Secondary indications include

- Bridge to transplant/ablation
- Downstaging to resection or transplantation size criteria
- Palliate patients with BCLC-C stage in select cases. Eg: Child A, segmental portal vein thrombosis and not tolerating systemic chemotherapy

12.4.1.2 Contraindications

Absolute Contraindications

1. Factors related to liver cirrhosis
   - Decompensated cirrhosis (Child-Pugh score > 8) including hepatic encephalopathy, jaundice, refractory ascites, uncorrectable coagulopathy
2. Factors related to HCC
   - Extensive tumor involving both the lobes of the liver (>70% of liver involvement by the tumor)

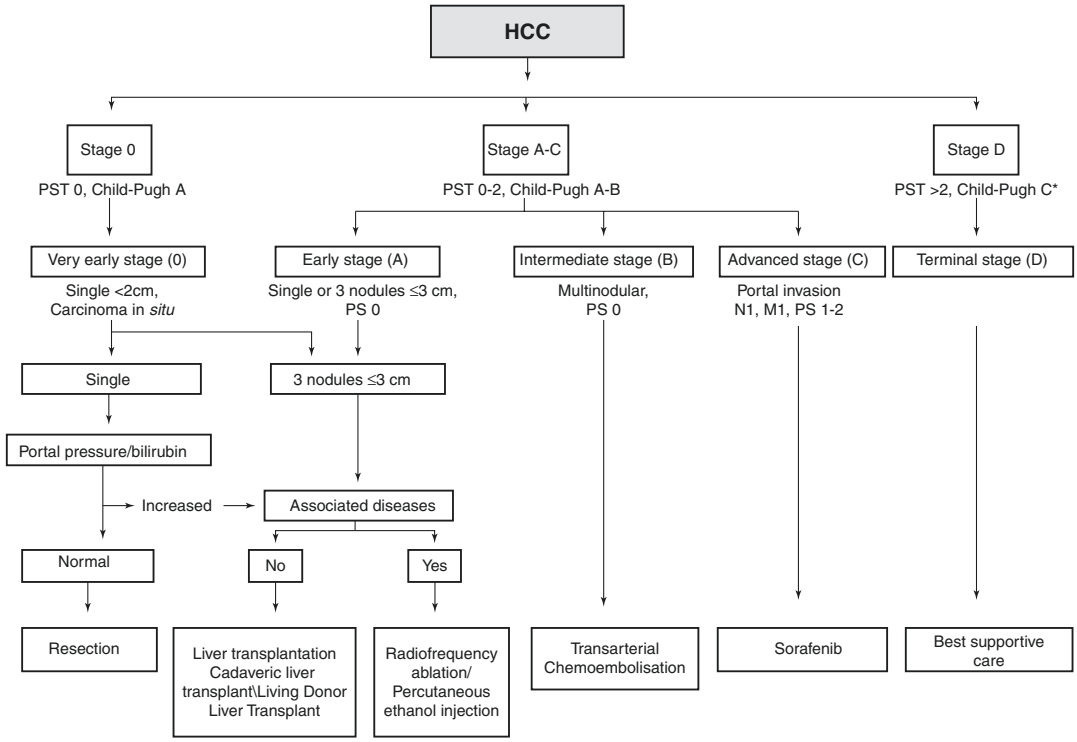

Fig. 12.12 Modified BCLC staging and treatment strategy

3. Contraindication to hepatic intra-arterial treatment
   - Untreatable arteriovenous fistula
4. Contraindications for the administration of chemotherapy
   - Severe thrombocytopenia or leukopenia
   - Moderate to severe cardiac or renal insufficiency (creatinine ≥2 mg/dL or creatinine clearance <30 ml/min
5. Contraindications for angiography
   - Anaphylactic reaction to contrast agent or chemotherapy drug
   - Uncorrected coagulopathy
6. Poor performance status (ECOG >2)

Relative Contraindications

- Untreated oesophageal varices at high risk of bleeding
- Biliary dilatation
- Portal vein thrombosis

12.4.1.3 Pre-Treatment Assessment

1. Tissue diagnosis or convincing clinical diagnosis based on imaging characteristics and relevant clinical data
2. Cross-sectional imaging of liver—Triphasic CECT or Dynamic MRI abdomen
3. Exclusion of extrahepatic disease
4. Laboratory evaluation
   (a) Complete blood cell count (CBC), liver function tests (LFT), Coagulation profile and renal function tests (RFT)
   (b) Baseline tumor markers—Serum Alfa fetoprotein (AFP)
   (c) 2D echocardiography

12.4.1.4 Procedure: TACE can be of two types, as described in section 12.3.2

1. Conventional TACE (cTACE):

cTACE at the author's institute is used to treat multifocal/multicentric HCC or in combination with ablation, as discussed previously (Fig. 12.13). During the procedure, 3D cone-beam CT is done at the author's institution, to delineate all the tumoral feeders. The presence of unopacified tumors by the hepatic arteries warrants search of the

extrahepatic supply supplying that portion. At the end of cTACE, cone-beam 3DCT is done to confirm and document adequate lipiodol deposition within the entire lesion (Fig. 12.14). In a follow-up CT scan after cTACE, lipiodol deposition can be seen in the following four patterns (Fig. 12.15). Type 1—compact homogeneous opacification of the tumor focus (Fig. 12.15a); Type 2—almost homogeneous opacification (Fig. 12.15b); Type 3—weak heterogeneous opacification (Fig. 12.15c); Type 4—very weak or no opacification of the tumor focus, which may warrant additional sessions of cTACE via extrahepatic tumoral feeders (Fig. 12.15d).

A dynamic contrast-enhanced MRI is preferred as a follow-up scan after cTACE, as it is more sensitive and accurate in diagnosing viable tumoral enhancement (Fig. 12.16). In comparison, the active portion of the tumor can get masked by streak artifacts in a CT scan from high-density partially deposited lipiodol.

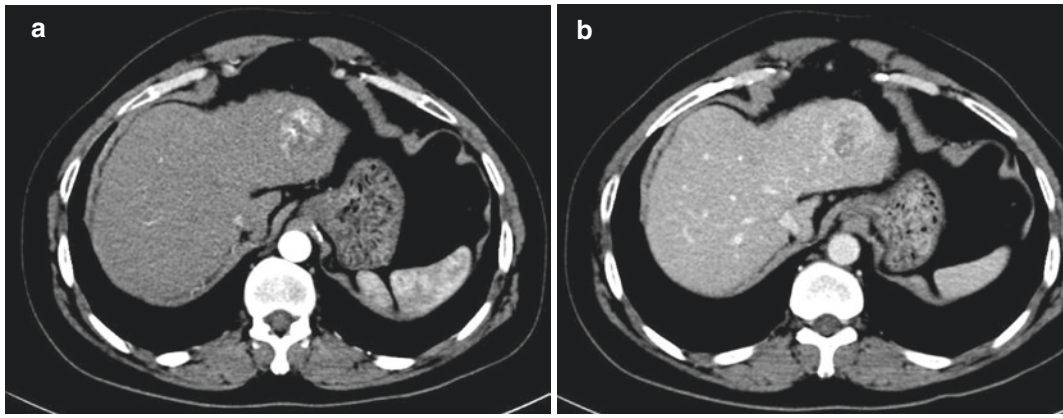

Fig. 12.13 (**a**, **b**) 49-year-old man with an incidentally detected liver tumor, showing arterial enhancement and venous washout, characteristic of HCC

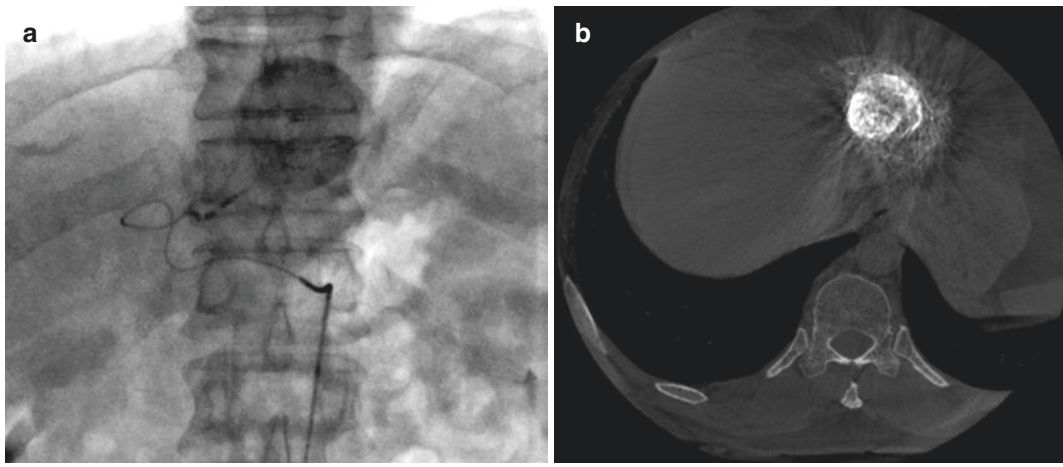

Fig. 12.14 (**a**, **b**) Fluoroscopic and cone-beam 3DCT images showing lipiodol deposition during and post-procedure, respectively

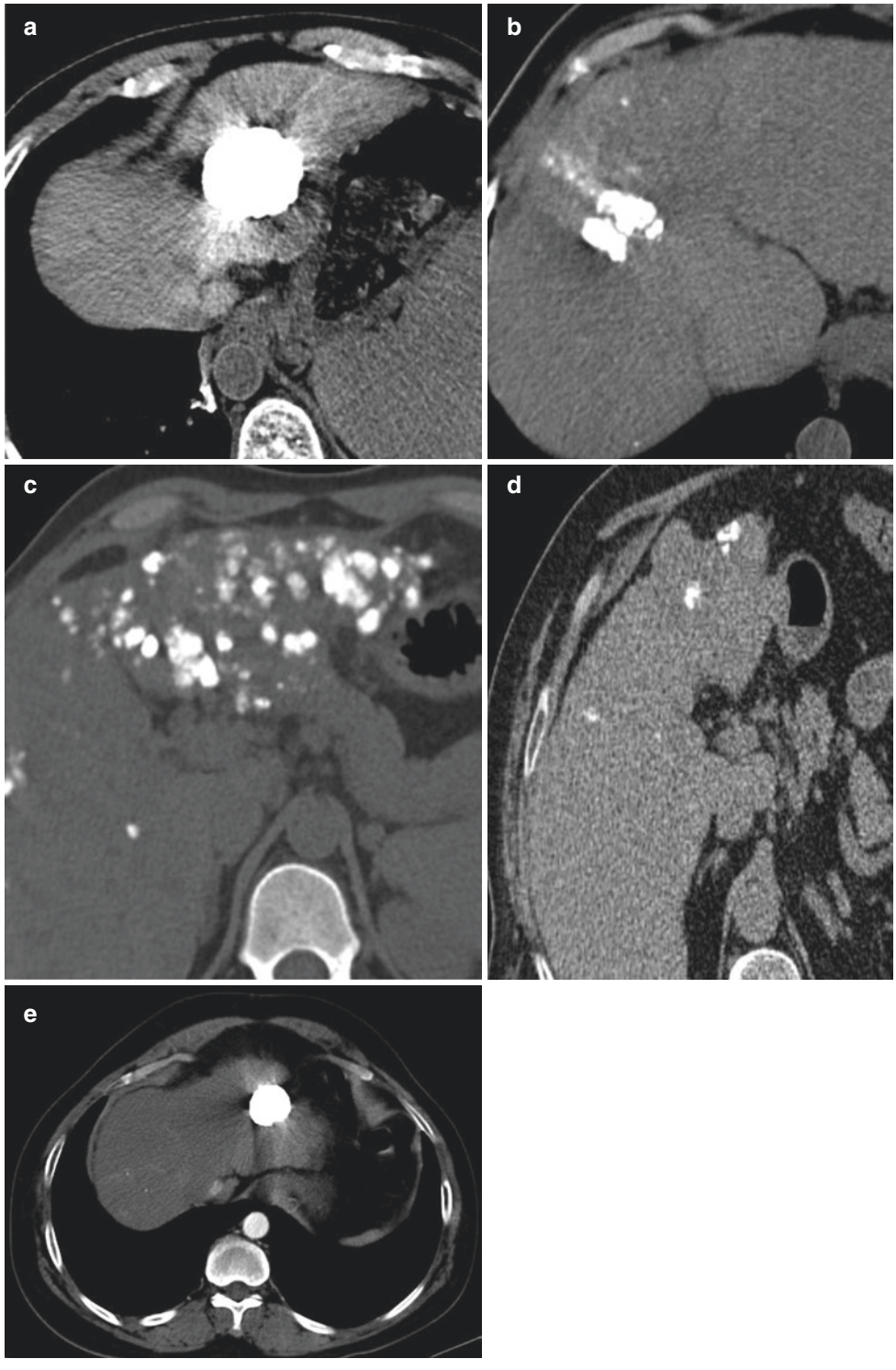

Fig. 12.15 (**a**–**d**) (from left to right): Types of lipiodol deposition on plain CT scan

2. Drug-Eluting Beads (DEB) TACE

Drug-eluting beads are loaded with doxorubicin for the treatment of hepatocellular carcinoma, which is released in a slow and sustained manner while ensuring high local and low systemic levels of drug concentration. At the author's institute, large HCCs (> 5 cm) supplied by 1–2 dominant arterial feeders are chosen for DEB-TACE. (Figs. 12.17 and 12.18).

Studies have demonstrated a reduced incidence of post-embolization syndrome and drug-related systemic and liver toxicity in the DEB-TACE group as compared to the cTACE group. In the PRECISION V trial comparing cTACE with DEB-TACE, the latter showed a trend toward higher response rates with regards to complete response, partial response, and disease control as compared to cTACE. DEB-TACE also demonstrated better tolerability despite higher doses of chemotherapy in the DEB-TACE group [11].

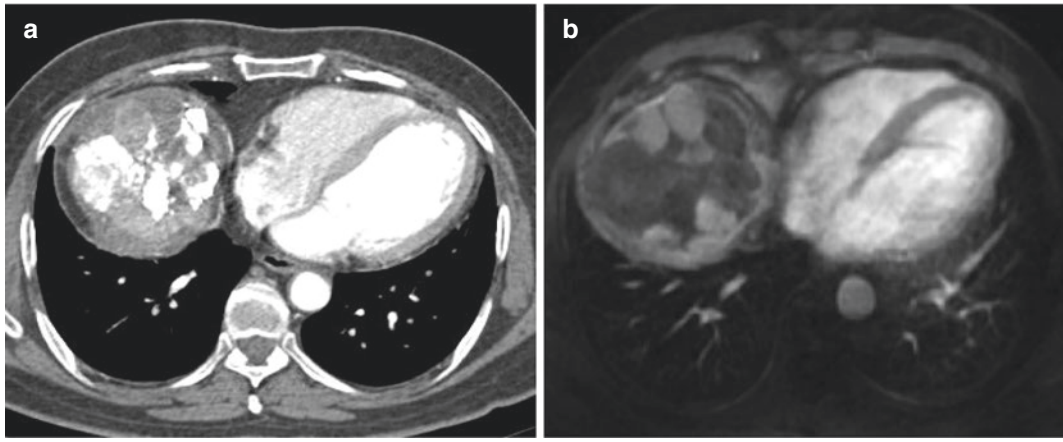

Fig. 12.16 (**a** , **b**) Post cTACE arterial phase CT image and arterial phase MRI showing residual disease. The non-lipiodol uptake viable tumor is better appreciated on MRI scan

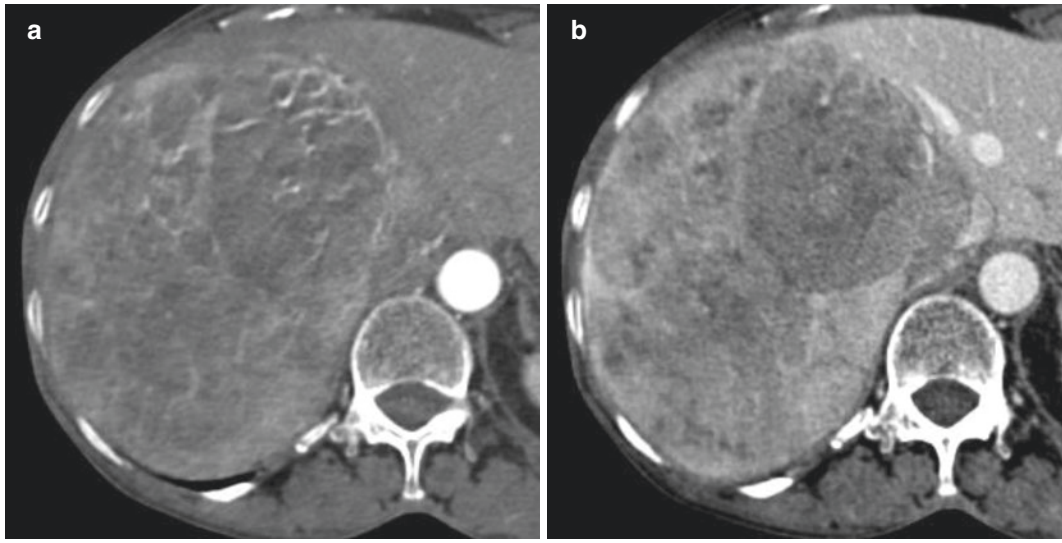

Fig. 12.17 (**a**, **b**) 55-year-old man, HbsAg positive, with a large arterially enhancing mass suggestive of hepatocellular carcinoma

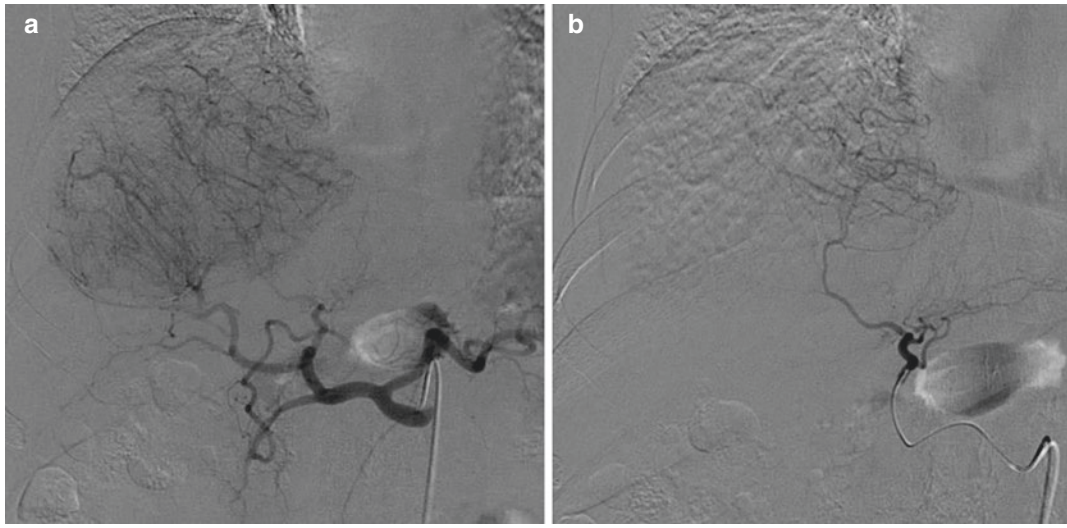

Fig. 12.18 (**a**, **b**) DSA images showing arterial feeders from both right and left hepatic arteries, DEB-TACE performed using 100–300 microns doxorubicin-loaded beads

12.4.1.5 Complications of TACE

The complications following TACE may be vascular or non-vascular. The most common non-vascular complication is post embolisation syndrome which manifests as abdominal pain, nausea, vomiting and fever. Other complications include hepatic abscess, sepsis, biliary stricture and hepatic decompensation. Vascular complications include injury at access site injury and hepatic artery, non-target embolisation to gall bladder which might result in prolonged post embolisation syndrome due to chemical cholecystitis. Embolisation of lipiodol can occur to the lung due to arterio-venous shunting resulting in chemical pneumonitis.

12.4.1.6 Follow-Up

1. Clinical assessment after 2 weeks, along with blood investigations (CBC, LFT, and RFT) to look for complications related to TACE.
2. Imaging assessment is done by dynamic MRI or Triphasic CT after 4–6 weeks for response evaluation and detect new lesions if any. The response is best assessed by *mRECIST* criteria [12] (Figs. 12.19 and 12.20)

12.4.1.7 Follow Up Treatment

TACE cycle is repeated at 4–6 weeks interval until 1. MRI or CT shows near-complete tumor necrosis. 2. Tumor does not respond after at least two sessions of TACE. 3. Down-staged to surgical or transplant criteria. 4. Develops a contraindication for TACE.

12.4.2 Transarterial Radioembolisation/Selective Internal Radiotherapy (SIRT) for HCC

Yttrium-90 radioembolization is another treatment modality for HCC in BCLC-C/B stage. The indications for SIRT in the case of Hepatocellular carcinoma include

1. BCLC-C—HCC with vascular invasion (Fig. 12.21).
2. BCLC-B—diffuse HCC, large HCC (>10cms), and HCC not responding to TACE [13].

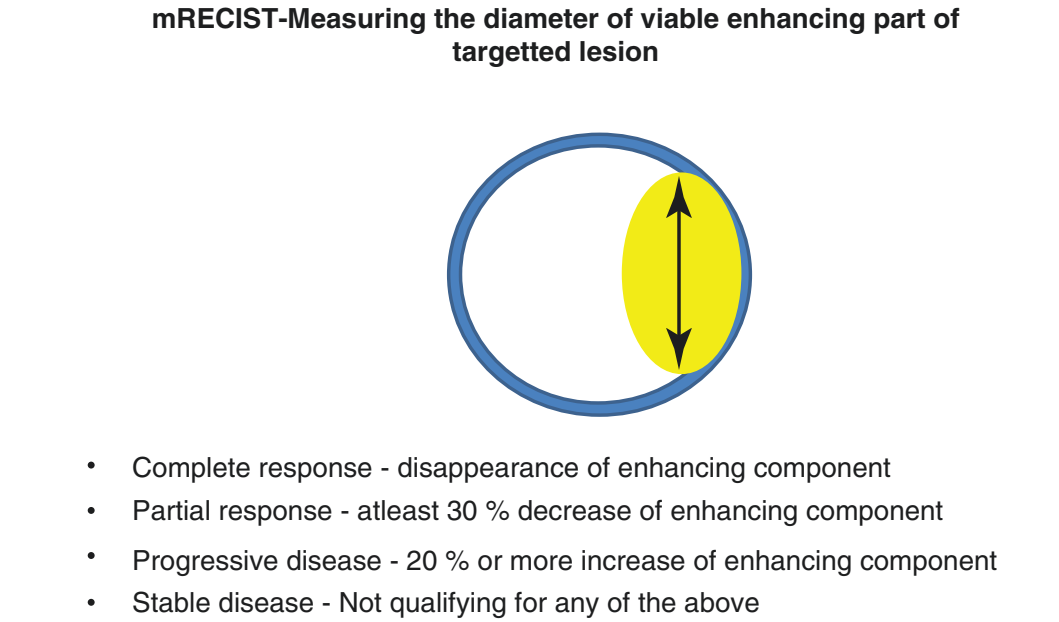

Fig. 12.19 mRECIST criteria

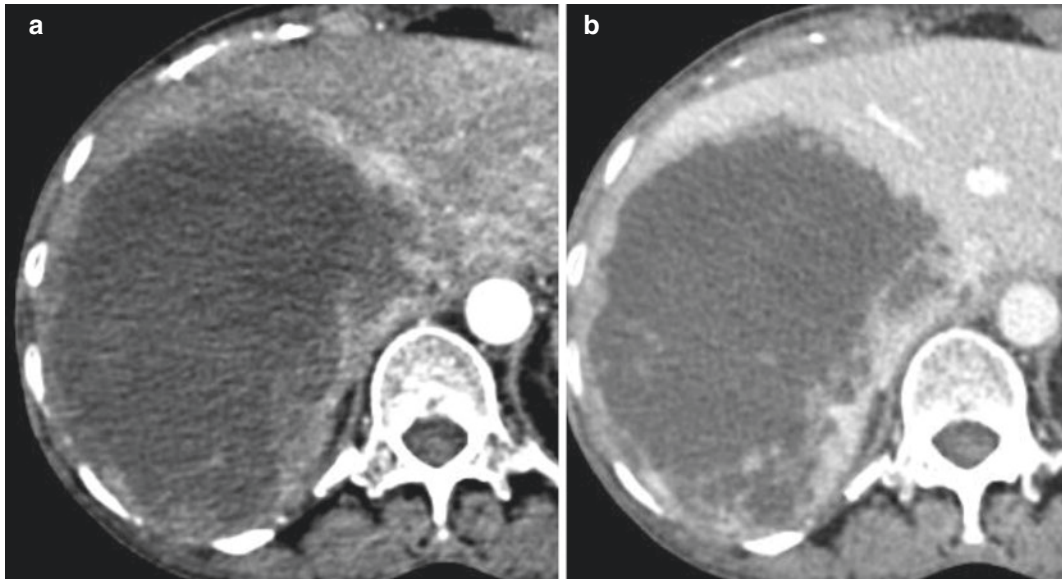

Fig. 12.20 (**a**, **b**) Follow-up after 6 weeks, significant necrosis with loss of enhancement except for the periphery suggestive of partial response

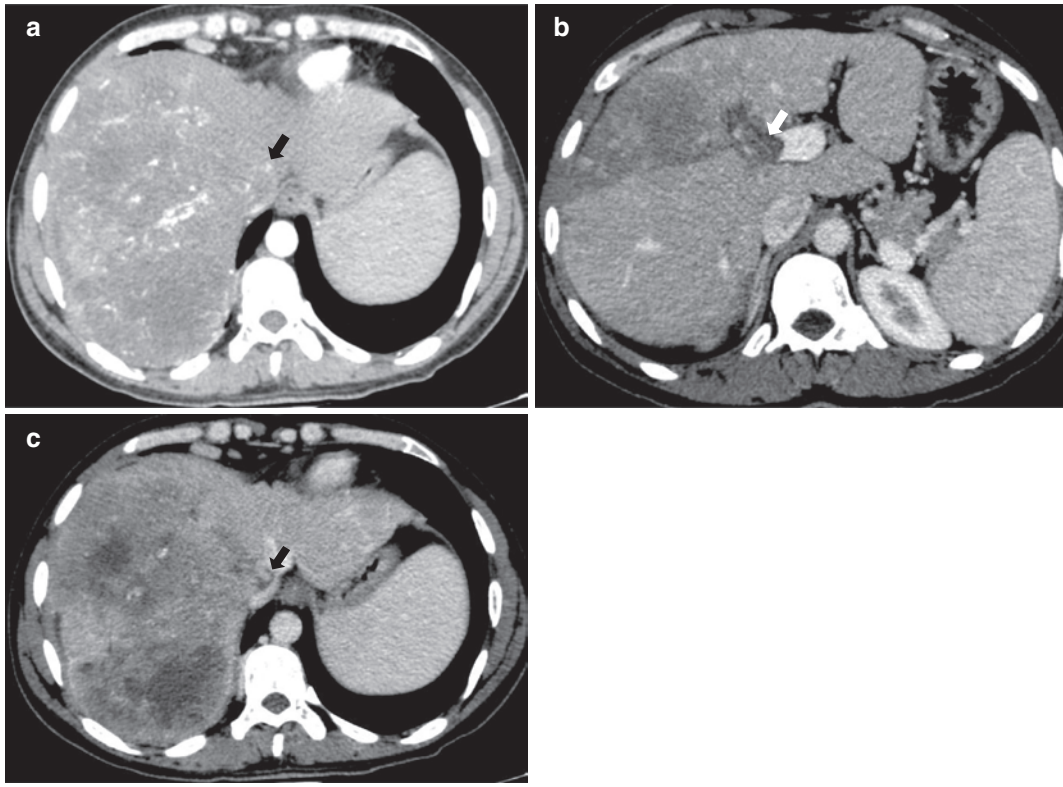

Fig. 12.21 (**a**–**c**) 33 year old man, HBV related chronic liver disease with large arterially enhancing HCC with right portal (white arrow) and hepatic vein thrombosis (black arrow)

The evaluation and procedural technique has been detailed in section 12.3.3. Following SIRT, the patient need not be isolated due to low tissue penetration. At our institute, a post radioembolisation PET scan is done within 24 hours to identify the distribution of Y90 within the tumor and rule out any inadvertant extrahepatic deposition (Fig. 12.22).

Follow-up imaging is done using CECT or Dynamic MRI abdomen after 6 weeks for response evaluation (Fig. 12.23). In bilobar disease, the whole liver can be treated in one session itself, or sequential lobar treatment may be given, depending upon the liver function, performance status of the patient, and institutional policy.

In Complications of SIRT include fever, nausea, pain, fatigue, and anorexia. Inadvertent embolization may lead to pancreatitis, gastritis, enteritis, cholecystitis, ulcerations, and radiation-induced pneumonia/pulmonary fibrosis.

In a meta-analysis done by Golfieri et al., response rates of HCC following SIRT ranged from 78 to 89% [14]. PREMIERE trial demonstrated that TARE with Y-90 glass microspheres had significantly longer time to progression as compared to cTACE (26 months vs. 6.4 months); however, no significant difference in overall survival was noted [15, 16]. PREMIERE trial demonstrated a potential role for TARE as a bridge to transplant due to a longer time for progression [17, 18]. A large retrospective study done by Salem et al. showed that there was no significant difference in median survival between TACE (20 months) and SIRT (17.5 months) groups [16].

SARAH trial demonstrated no survival benefit between Y-90 resin microspheres and sorafenib in patients with locally advanced HCC [15, 19].

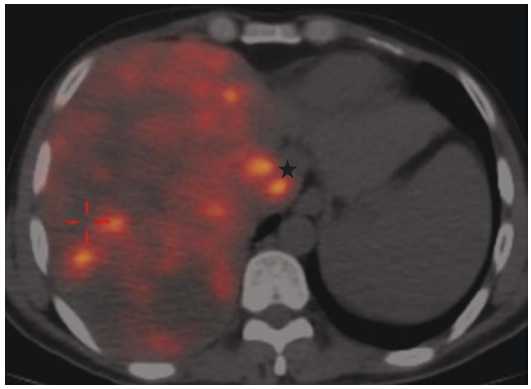

Fig. 12.22 PET—Image acquired at 14 h post injection. Selective tracer localization seen in the tumour and hepatic vein thrombosis extending into IVC (Asterisk)

However, patients receiving Y-90 resin microspheres had reduced side effects, a better quality of life, higher response rates, and improved tumor progression in the liver as compared to the patients who received sorafenib.

12.5 Hepatoblastoma

Hepatoblastoma is the most common pediatric liver malignancy comprising ~1% of all pediatric malignancies [20]. Complete surgical resection is vital to cure to patients with hepatoblastoma; however, ~ 50% of patients present with advanced and unresectable hepa-

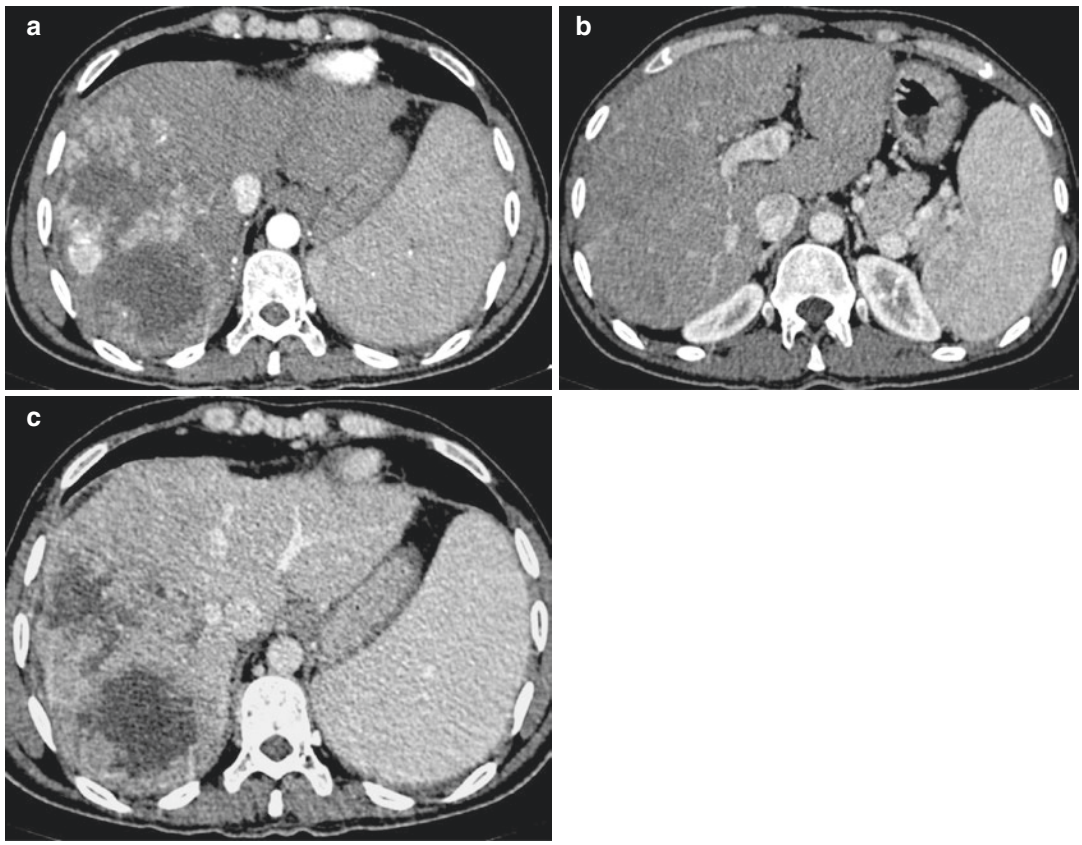

Fig. 12.23 (**a**–**c**) Follow up CECT after 3 months showing significant decrease in size and enhancement of the tumour

toblastoma [20]. Large tumor size, porta hepatis invasion, and metastatic spread are associated with poor patient prognosis [20–22]. Hepatoblastoma has an excellent response to chemotherapy; therefore, preoperative systemic chemotherapy improves the prognosis of the patients [19]. Systemic chemotherapy is known to have side effects like cardiac and bone marrow toxicity, which occasionally are significant. Transarterial chemoembolization (TACE) helps to deliver a much higher concentration of chemotherapeutic agents to the tumor as compared to systemic chemotherapy with fewer side effects. Chemotherapeutic agents used are adriamycin (20–30 mg/m^2) emulsified in lipiodol and cisplatin (40–60 mg/m^2) followed by gel foam embolization [19]. In the author's institution, chemoembolization is performed using drug-eluting beads loaded with Adriamycin (20–30 mg/m^2) and Cisplatin (40–60 mg/m^2). (Figs. 12.24 and 12.25).

In a reported series by Zhang et al., 24 patients with unresectable hepatoblastoma demonstrated significant reduction in tumor volume (46.1%–90.2%) associated with a substantial decrease in AFP values (63.8%–99.9%) following TACE [20]. Twenty-two patients underwent complete resection, and two patients underwent partial resection in their series.

12.6 Colorectal Cancer with Liver Metastases

Metastatic lesions are the most common neoplasm identified in the liver. In colorectal cancers, the liver is the most common and often the only site of metastases [15, 23, 24]. Eighty percent of the patients with colorectal cancers have liver metastases, and 50% of the patients have liver metastases at initial presentation [15]. While surgical resection is the standard of care of liver limited disease, < 20% are candidates for liver resection, and recurrence rates are as high as 75%. Those patients who are not ideal candidates for surgical resection are given systemic chemotherapy with a mean survival of 12–19.5 months [15].

Drug-eluting beads with Irinotecan (DEBIRI TACE) results in median survival of 15–25 months, which is comparable with the results achieved with systemic chemotherapy, however, with lesser systemic side effects [15, 23, 24]. It may be useful in downstaging the unresectable metastatic liver disease for surgery or ablative therapy [25] providing a higher and prolonged intra-tumoral dose of Irinotecan. There was improvement in disease-free survival after DEBIRI with partial and complete response rates ranging from 36–78%, based on RECIST criteria, and durable response to 12 months [15] (Figs. 12.26 and 12.27). Patients

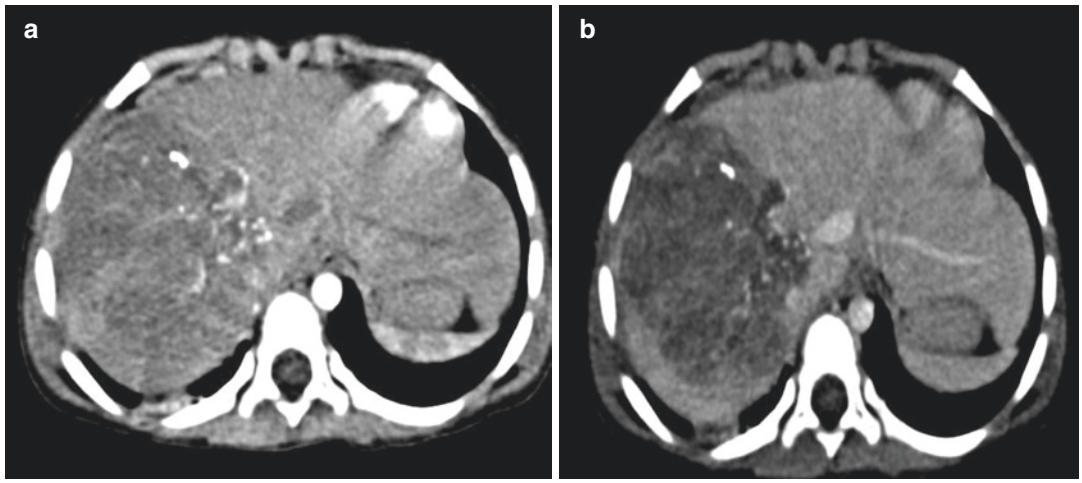

Fig. 12.24 (**a**, **b**) A 3-year-old girl with hepatoblastoma in the right lobe and inadequate FLR for extended right hepatectomy underwent two cycles of DEB-TACE with doxorubicin and cisplatin

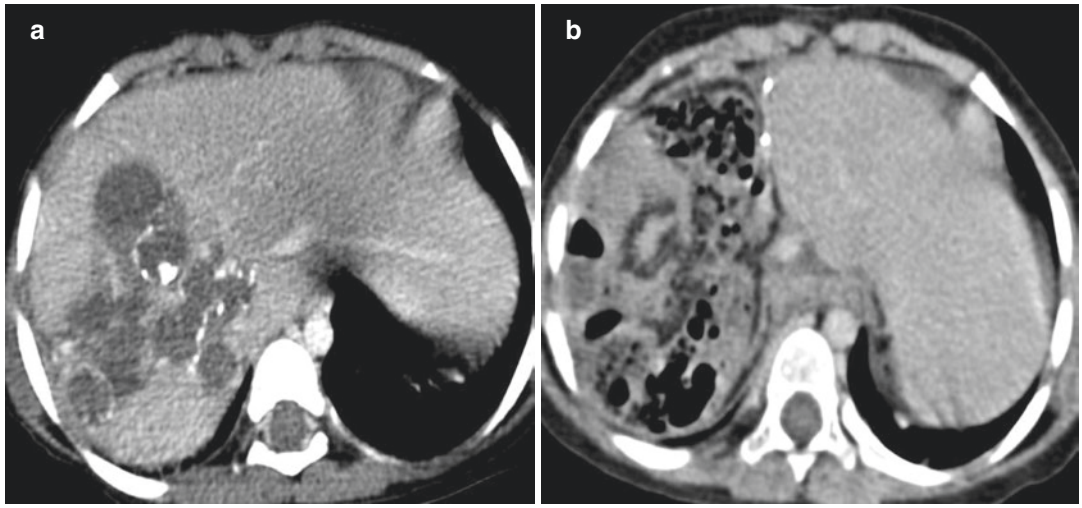

Fig. 12.25 (**a**, **b**) Follow-up CECT after 6 weeks reveals excellent response with a significant reduction in the size of the tumor and hypertrophy of contralateral lobe. The child underwent right hepatectomy without postoperative decompensation

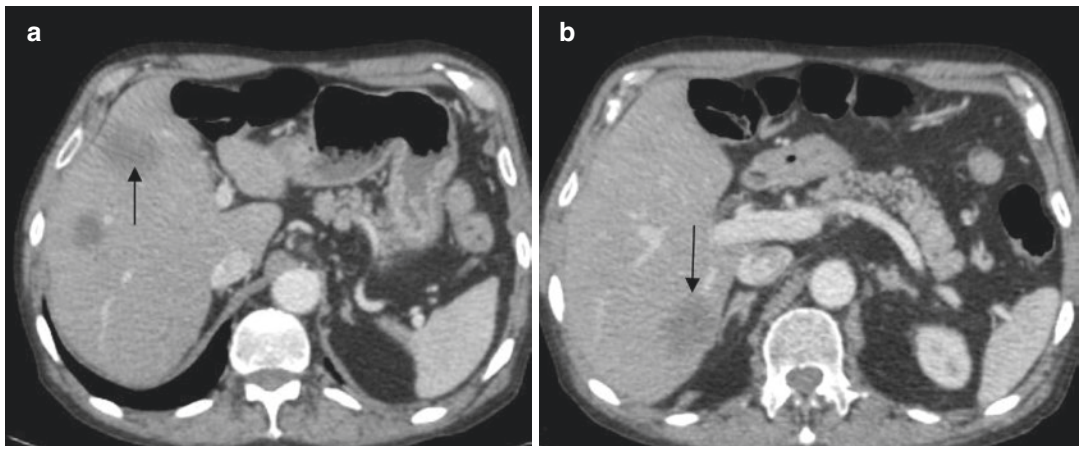

Fig. 12.26 (**a**, **b**) 59 years old male with colorectal carcinoma with multiple liver metastases. CECT showing multiple liver lesions in the right lobe of the liver

treated with DEBIRI experienced bad post-embolization syndrome and required approximately four sessions to complete one cycle of treatment as compared to TARE [15].

The value of radioembolization using Y-90 resin microspheres in combination with systemic chemotherapy in patients with unresectable liver only or liver dominant metastatic colorectal cancer was demonstrated in SIRFLOX trial [15]. The patients were randomized to receive Y-90 resin microspheres (SIR-Spheres) in combination with modified FOLFOX chemotherapy (with or without bevacizumab) or modified FOLFOX chemotherapy alone (with or without bevacizumab). The progression-free survival with radioembolization improved from 12.6 to 20.5 months and decreased the risk of tumor progression by 31%. The overall survival or overall progression-free survival in patients with liver only and liver dominant metastatic colorectal cancer showed no improvement in despite higher response rates and improved liver-specific progression-free survival with the

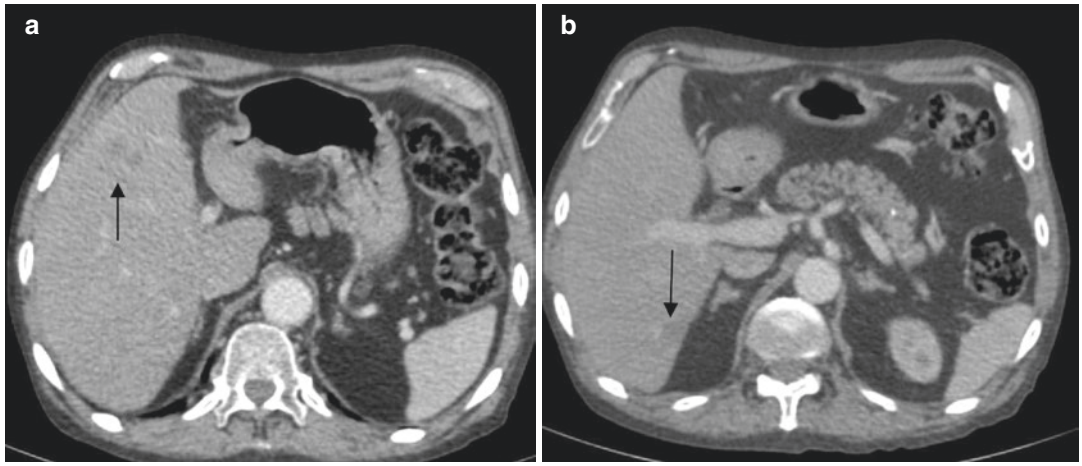

Fig. 12.27 (**a**, **b**) Post-DEBIRI TACE showing a decrease in the number of these lesions with decreased size and enhancement. No new lesion is seen

addition of Y-90 to first-line chemotherapy [15, 23]. As of the latest update of the National Comprehensive Cancer Network Clinical Practice Guideline in Oncology for colon and rectal cancer, treatment withY-90 resin microspheres is included as a Category 2A recommended treatment for patients with liver dominant, chemotherapy-resistant colorectal disease (Figs. 12.28 and 12.29).

12.7 Cholangiocarcinoma

Cholangiocarcinoma is a rare malignancy with poor prognosis and has an overall 5-year survival rate of <5%. Only 30% of patients present at the resectable stage and recurrence is common even after complete resection. Transarterial therapies are safe and effective in the treatment of intrahepatic cholangiocarcinoma. Though the response rate is comparable for TACE, TARE, and chemoinfusion, higher rates of partial and stable responses were reported with TARE (Fig. 12.30). The overall 1-year survival rates are similar between chemotherapy and radiotherapy. The median overall survival for intra-arterial therapy was 13 months as compared to 11 months for systemic chemotherapy [15].

12.8 Melanoma

The most common site for metastases of ocular and cutaneous melanoma is the liver. Median survival in patients with hepatic metastases is poor, averaging ~2–7 months [15]. Several studies have shown TACE to have a more significant benefit than standard immunotherapy [15, 23]. The overall survival in patients who receive hepatic arterial infusion, TACE, or immuno-embolization ranges between 6–21 months [15] (Fig. 12.31). TARE had a superior overall survival rate and is a safe and effective salvage therapy for limited metastases [15].

12.9 Breast Cancer with Liver Metastases

Breast cancer is the second most cancer worldwide after lung cancer [15]. Up to 48% of metastatic breast cancer has liver metastases, and median survival is 14.2–16.8 months if there is extrahepatic spread and 22.7–27.2 months if metastases are confined to the liver [15]. Treatment with DEB-TACE with doxorubicin or cTACE with mitomycin C plus gemcitabine shows compelling support for their use with

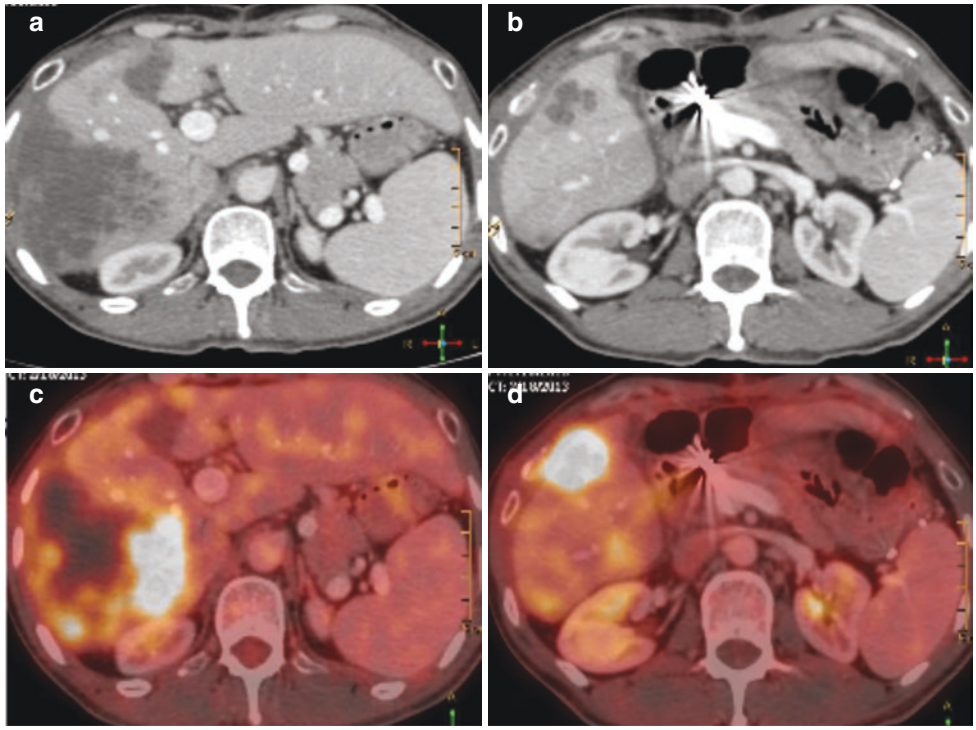

Fig. 12.28 (**a**–**d**) A 50-years old patient of colorectal carcinoma with liver metastases. PET—CECT images show enhancing lesions in segment V and VI with areas of FDG uptake

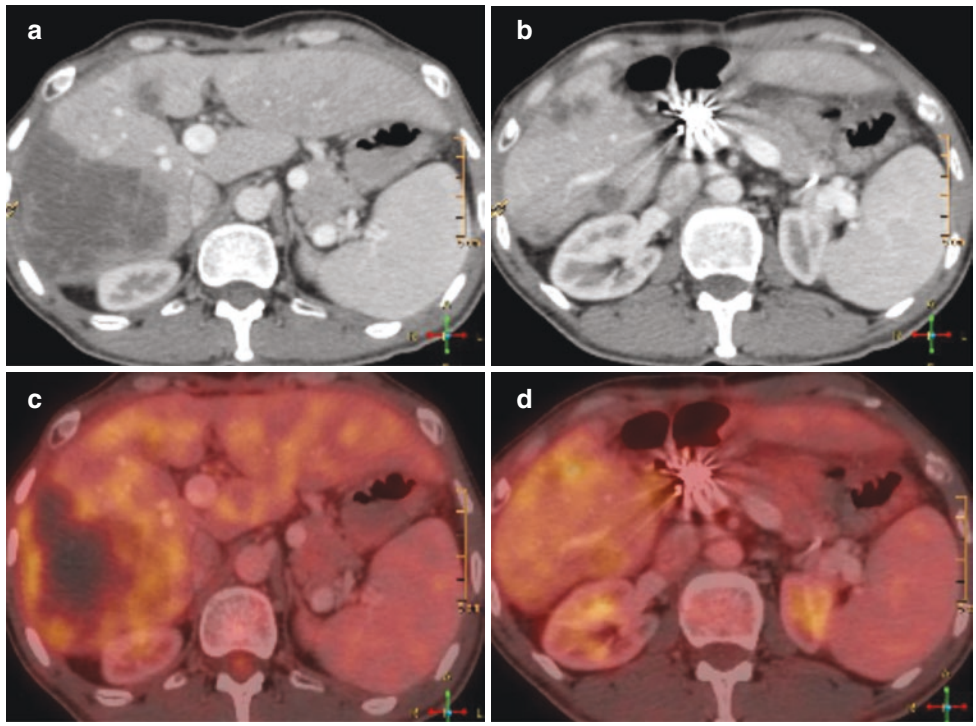

Fig. 12.29 (**a**–**d**) Follow up PET- CECT, 3 months after TARE shows excellent response in the form of decreased FDG uptake

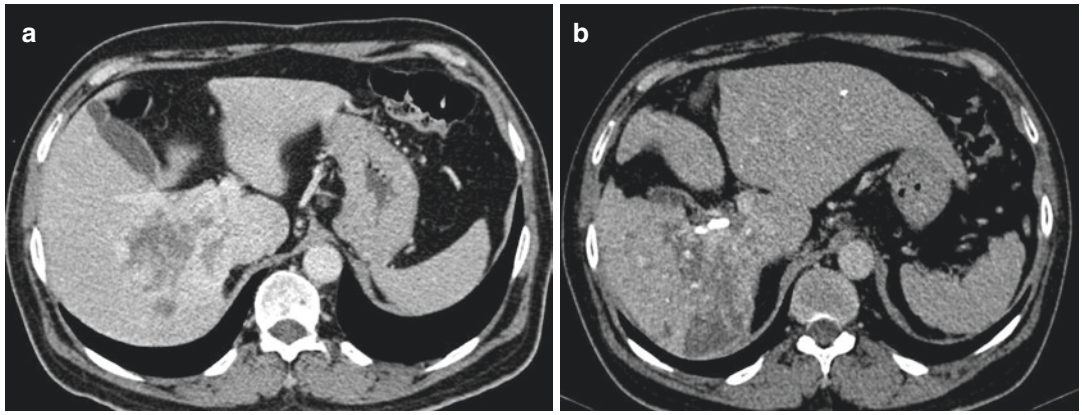

Fig. 12.30 (**a**) 59-year-old man, presenting with abdominal pain, CECT scan revealing enhancing mass. Biopsy suggestive of cholangiocarcinoma. Two cycles of TACE done using 100 mg of gemcitabine and 50 mg of cisplatin. (**b**) Follow-up after two cycles of TACE, good response with a decrease in enhancement. The patient successfully underwent right hepatectomy

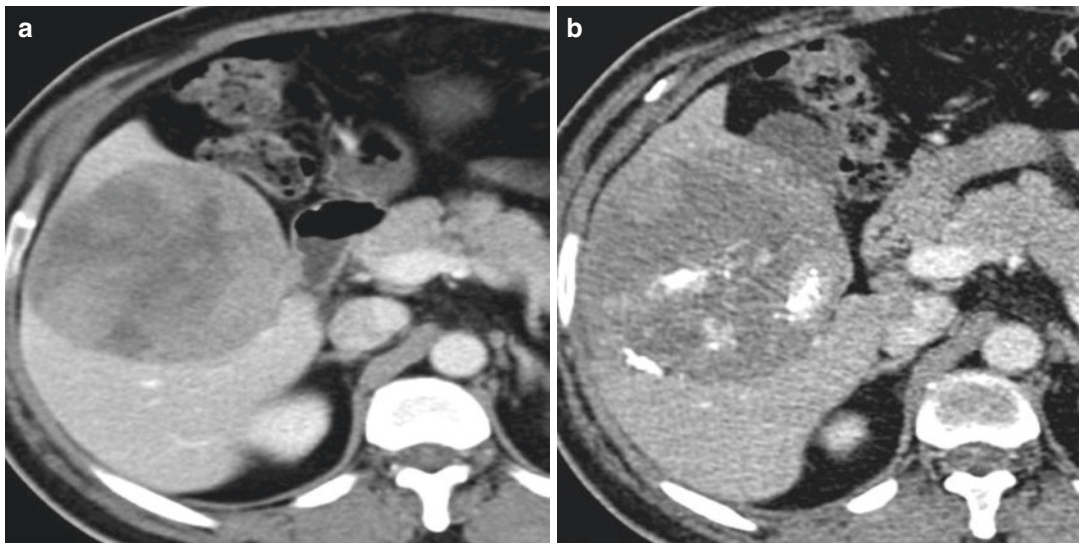

Fig. 12.31 (**a**) 55 years old male with a known case of right ciliary body malignant melanoma with liver metastases. Pre TACE CT showed a large mass in segment V & VI of the liver. TACE was done using 200 mg of dacarbazine mixed with lipiodol. (**b**) Post-TACE CT shows reduction in the enhancement of the tumor

overall survival rates up to 47 and 35 months, respectively [15, 23] (Fig. 12.32).

12.10 Neuroendocrine Tumors

Neuroendocrine tumors (NET's) include a variety of tumors that have the capacity to synthesize and secrete hormonally active polypeptides. They include medullary carcinoma thyroid, pancreatic NET (islet cell carcinoma), carcinoid tumor, pheochromocytoma, etc. They have a predisposition for hepatic metastases, and 46 to 93% of patients with NET's have hepatic metastases at presentation [15]. Liver metastases impair quality of life and are associated with 5-year survival rates of 20–25% [26]. Treatment options include somatostatin analog therapy, surgical resection with curative intent in a small percentage of patients (10–

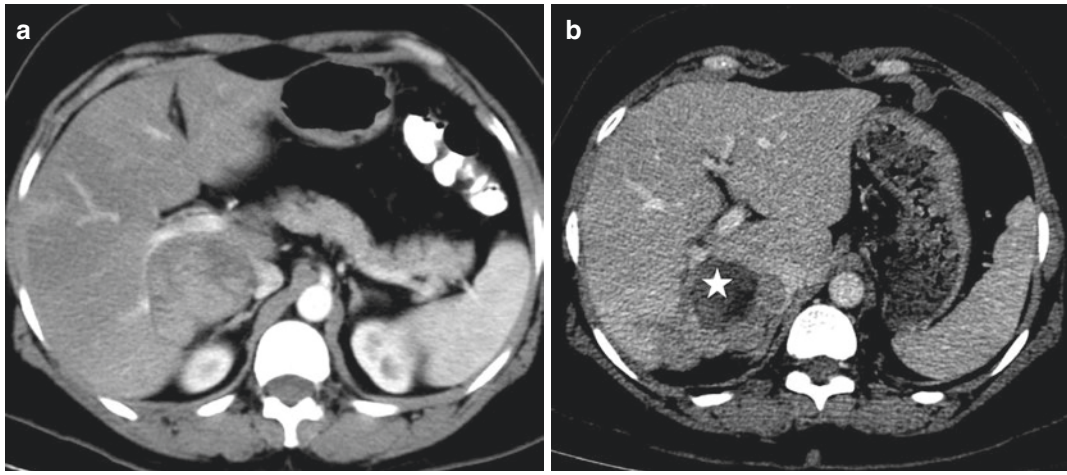

Fig. 12.32 (**a**) A 40-year-old female who had undergone modified radical mastectomy for carcinoma of right breast and chemotherapy, presented with a solitary metastasis in caudate lobe of the liver and underwent a session of TACE. (**b**) Follow-up CECT after 3 months reveal a reduction in the enhancement of index tumor (*) and atrophy of segment VI secondary to TACE

15%), systemic chemotherapy, and intra-arterial treatment.

The choice of Intra-arterial therapy may be TAE, TACE or TARE based on differentiation and grading of the tumor, presence or absence of symptoms from secreting tumors and response to systemic therapy. The indication for liver directed therapy include.

Indications

- Liver dominant disease who have symptoms related to hormonal excess or tumor bulk
- Rapid progression of liver disease, especially in refractory, unresectable, or recurrent disease
- Adjuvant therapy before hepatic resection, tumor ablation, or liver transplantation.

The procedural techniques have been described in section 12.3. At our institution, we prefer to perform TAE in Grade I NET, TACE using doxorubicin in grade II NET, and TARE with systemic therapy in liver dominant grade III metastatic NET [26]. Patients with unilobar disease may be treated with either lobar embolization or selective embolization of individual branches supplying the tumor (Figs. 12.33, 12.34, and 12.35). Patients with bilobar disease undergo staged embolization, as embolization of the entire liver may lead to liver decompensation [27]. Patients with grade I and II NET are started on octreotide, ½ an hour before the procedure, and continued up to 24 hours to prevent adverse reactions due to release of hormones during the intra-arterial treatment.

Although there is no absolute contraindication for chemoembolization, complete portal vein thrombosis, poor performance status, and hepatic insufficiency are considered relative contraindications. Embolization should not be done in patients with bilirubin >2–3 mg/dL.

Patients who have undergone biliary-enteric anastomosis are prone to develop liver abscess after chemoembolization and should be started on prophylactic antibiotics and should undergo bowel preparation before the procedure. Prophylactic treatment with moxifloxacin (400mg by mouth daily beginning 3 days before and continuing for 17 days after the procedure alone was successful in preventing liver abscess in patients with biliary-enteric anastomosis, who were treated with chemoembolization, avoiding the need for bowel preparation [27, 28].

Those patients who were symptomatic due to liver dominant NET metastases and underwent HAE, TACE, or Y90 TARE showed 90–100% reduction in symptoms [15]. In patients with carcinoid tumors, no improve-

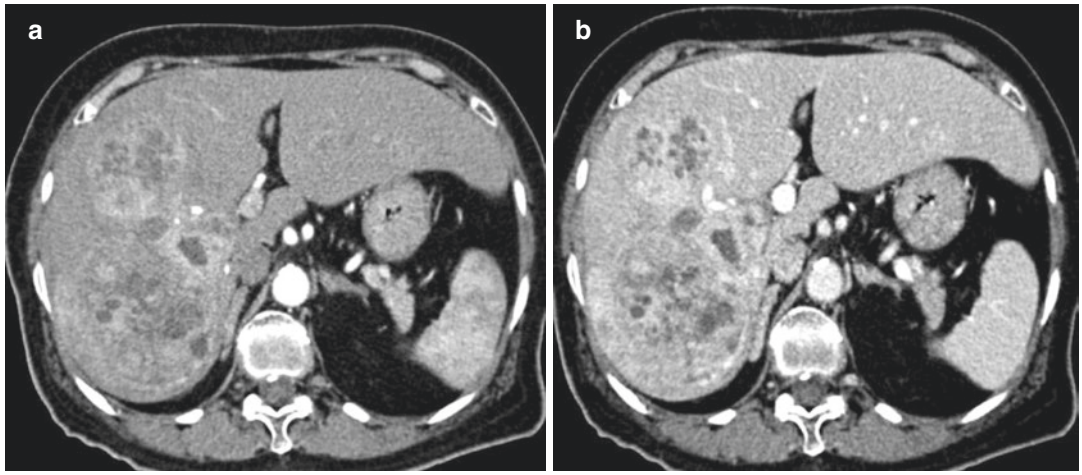

Fig. 12.33 (**a**, **b**) 69-year-old woman with jejunal NET with liver metastasis, large masses in the right lobe of the liver

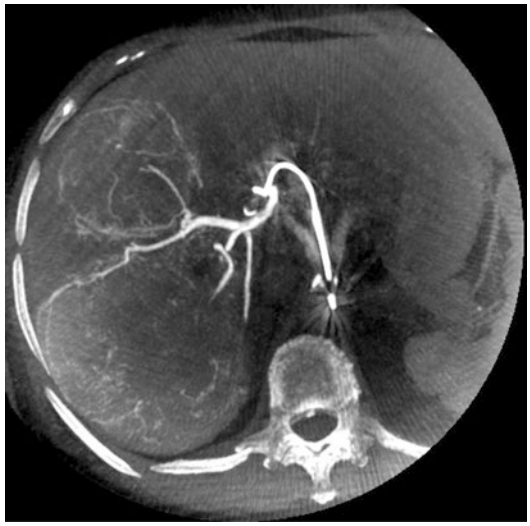

Fig. 12.34 DSA and Cone-Beam 3D CT showing hypervascular masses supplied by the right hepatic artery and underwent transarterial embolization

ment in overall survival or progression-free survival group in the TACE group vs. HAE group. In patients with islet cell pancreatic tumors, there was survival improved to 31.5 months from 18.2 months and response rate to 50% from 25% in the TACE group as compared to the HAE group [26]. No significant differences were noted in complications or toxicities between HAE and TACE. No clear advantage of one embolotherapy over others is described in the literature [15, 26–29].

TARE with Y-90 microspheres is safe with high response rates, even with a significant tumor burden in the liver. Median survival rates have been demonstrated to up to 70 months with a low incidence of acute and delayed toxicities [15, 26].

12.11 Hemangioma

Haemangiomas are the most common benign tumors of the liver, with a prevalence of 3% to 20% [30]. While most liver hemangiomas are small and require no treatment; few giant (more than 5 cm in size) hemangiomas are symptomatic and need surgical intervention like liver resection or enucleation [30]. Complications like bleeding, Kasabach–Merritt syndrome, and organ or vessel compression can occur with giant hemangiomas. Transcatheter arterial embolization (TAE) can be used before surgical intervention and as an emergency treatment to control bleeding in case of rupture of giant haemangioma.

TAE is a safe and effective method for the treatment of symptomatic hepatic haemangiomas [30] and has demonstrated a significant decrease

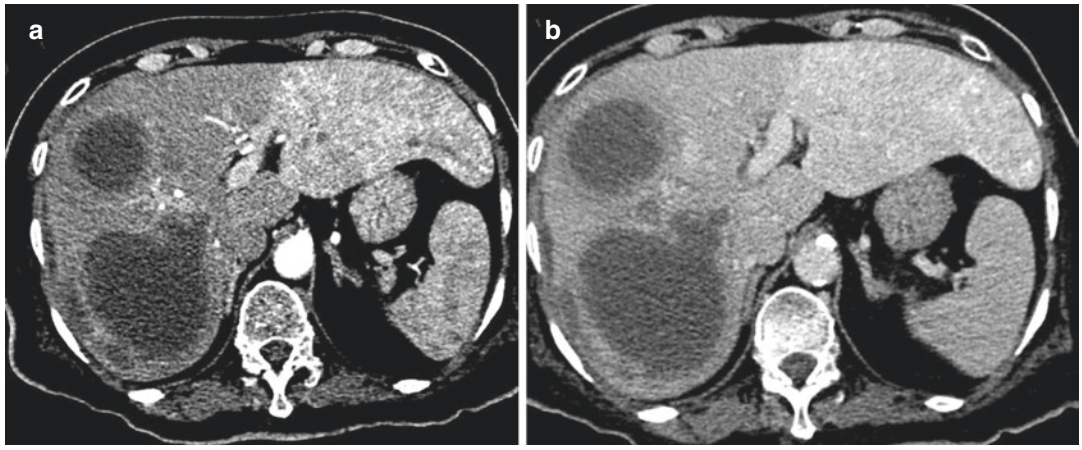

Fig. 12.35 (**a**, **b**) Post-one cycle of TAE on follow-up, near-complete loss of enhancement noted suggestive of complete response

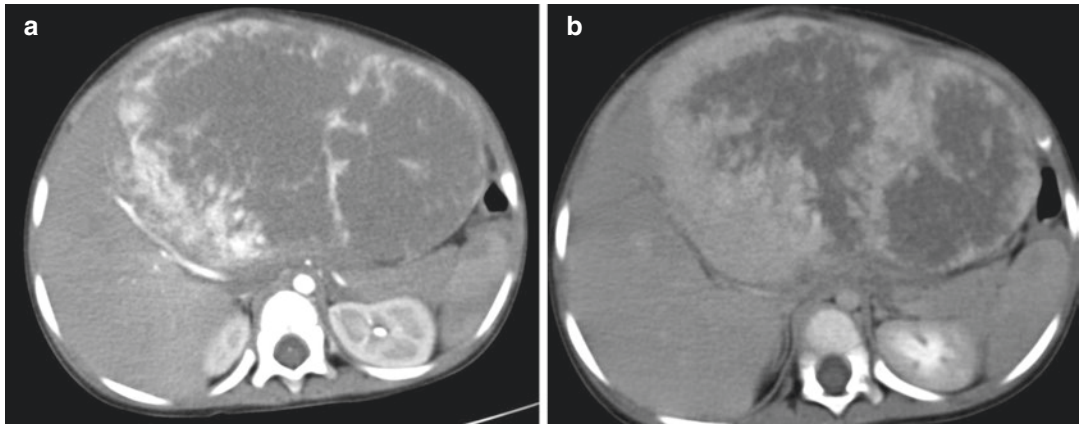

Fig. 12.36 (**a**, **b**) 3-year-old male child presented with progressive abdominal swelling. CECT scan showing large mass with progressive enhancement suggestive of haemangioma/Hemangioendothelioma

in the size of lesions at 6 and 12 months of follow-up. However, long terms results for patients undergoing TAE for liver haemangiomas are not satisfying [31]. In patients with asymptomatic haemangiomas, TAE should not be performed due to the risk of complications which may include abscess formation, septicemia, biliary tree damage, renal failure, bowel infarction, and post-embolization syndrome.

Epithelioid hepatic haemangioendothelioma (EHE) [32] is a rare tumor of endothelial and connective tissue origin, resembling hemangioma and is typically seen in young females between 20–40 years of age. Most patients present with disseminated disease and prognosis involving both lobes of the liver, and the prognosis without treatment is poor. Several methods available currently for management include surgery (liver resection and transplantation), chemotherapy, transarterial treatments (TAE/TACE) (Figs. 12.36 and 12.37), radiotherapy, and radiofrequency ablation (RFA). Multifocal unresectable EHE may be an indication for liver transplantation. TAE seems to be an acceptable bridge treatment in patients awaiting liver transplantation [33].

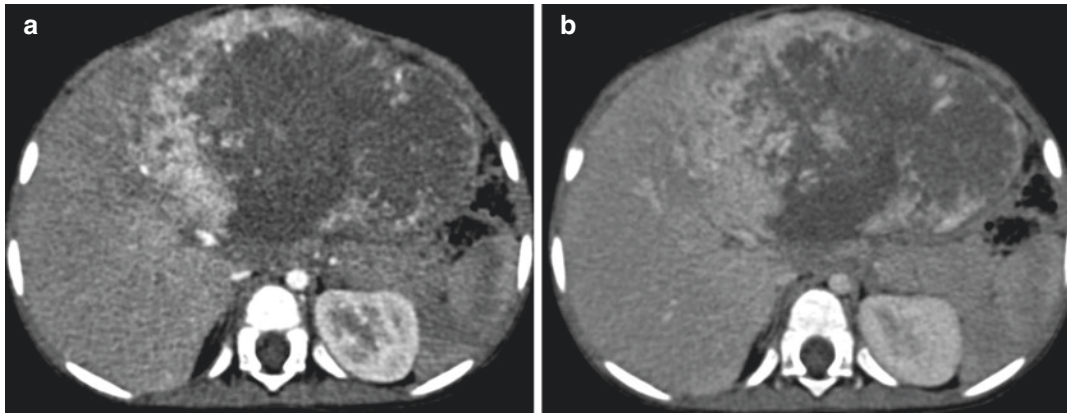

Fig. 12.37 (**a**, **b**) Follow-up imaging after two sessions of TAE shows reduced enhancement suggesting good response

12.12 Conclusion

Transcatheter directed intra-arterial therapies are regarded as an effective therapy for liver limited tumors. They are now offered as treatment strategy owing to their minimal toxicity profiles and highly effective tumor responses while sparing the normal hepatic parenchyma. These unique characteristics, coupled with their minimally invasive nature, provide an attractive therapeutic option for patients, who in the past, may have had fewer alternatives.

References

1. Kumar A, Srivastava DN, Chau TTM, Long HD, Bal C, Chandra P, et al. Inoperable hepatocellular carcinoma: transarterial 188Re HDD-labeled iodized oil for treatment--prospective multicenter clinical trial. Radiology. 2007 May;243(2):509–19.
2. Park YN, Yang CP, Fernandez GJ, Cubukcu O, Thung SN, Theise ND. Neoangiogenesis and sinusoidal "capillarization" in dysplastic nodules of the liver. Am J Surg Pathol. 1998 Jun;22(6):656–62.
3. Sigurdson ER, Ridge JA, Kemeny N, Daly JM. Tumor and liver drug uptake following hepatic artery and portal vein infusion. J Clin Oncol Off J Am Soc Clin Oncol. 1987 Nov;5(11):1836–40.
4. Konno T, Maeda H, Yokoyama I, Iwai K, Ogata K, Tashiro S, et al. Use of a lipid lymphographic agent, lipiodol, as a carrier of high molecular weight antitumor agent, smancs, for hepatocellular carcinoma. Gan To Kagaku Ryoho. 1982 Nov;9(11):2005–15.
5. Covey AM, Brody LA, Maluccio MA, et al. Variant hepatic arterial anatomy revisited: digital subtraction angiography performed in 600 patients. Radiology. 2002;224(2):542–7.
6. Kim HC, Chung JW, Lee W, Jae HJ, Park JH. Recognizing extrahepatic collateral vessels that supply hepatocellular carcinoma to avoid complications of transcatheter arterial chemoembolization. Radiographics. 2005 Oct;25(suppl_1):S25–39.
7. EASL Clinical Practice Guidelines. Management of hepatocellular carcinoma. J Hepatol. 2018 Jul 1;69(1):182–236.
8. Raza A, Sood GK. Hepatocellular carcinoma review: current treatment and evidence-based medicine. World J Gastroenterol. 2014 Apr 21;20(15):4115–27.
9. Vogl T, Gruber-Rouh T. HCC: Transarterial therapies—what the interventional radiologist can offer. Dig Dis Sci. 2019 Mar;5:64.
10. Vogel A, Cervantes A, Chau I, Daniele B, Llovet J, Meyer T, et al. Hepatocellular carcinoma: ESMO clinical practice guidelines for diagnosis, treatment, and follow-up. Ann Oncol Off J Eur Soc Med Oncol. 2018, Jan;29(Suppl 4):iv 238–55.
11. Vogl TJ, Lammer J, Lencioni R, Malagari K, Watkinson A, Pilleul F, Denys A, Lee C. Liver, gastrointestinal, and cardiac toxicity in intermediate hepatocellular carcinoma treated with PRECISION TACE with drug-eluting beads: results from the PRECISION V randomized trial. Am J Roentgenol. 2011 Oct;197(4):W562–70.
12. Arslanoglu A, Seyal AR, Sodagari F, Sahin A, Miller FH, Salem R, et al. Current guidelines for the diagnosis and Management of Hepatocellular Carcinoma: a comparative review. Am J Roentgenol [Internet]. 2016 Aug 4 [cited 2019 Aug 3]; Available from https://www.ajronline.org/doi/full/10.2214/AJR.15.15490
13. Sacco R, Mismas V, Marceglia S, Romano A, Giacomelli L, Bertini M, et al. Transarterialradioembolization for hepatocellular carcinoma: an update and perspectives. World J Gastroenterol. 2015 Jun 7;21(21):6518–25.

14. Ahmadzadehfar H, Sabet A, Biermann K, Muckle M, Brockmann H, Kuhl C, et al. The significance of Tc-99m-MAA SPECT/CT liver perfusion imaging in treatment planning for Y-90-microsphere selective internal radiation treatment. J Nucl Med Off Publ Soc Nucl Med. 2010 Aug 1;51:1206–12.
15. Ma J, Gimenez JM, Sandow T, Devun D, Kirsch D, Gulotta P, et al. Intraarterial liver-directed therapies: the role of interventional oncology. Ochsner J. 2017;17(4):412–6.
16. Mosconi C, Cappelli A, Pettinato C, Golfieri R. Radioembolization with Yttrium-90 microspheres in hepatocellular carcinoma: role and perspectives. World J Hepatol. 2015 Apr 18;7(5):738–52.
17. Bouvry C, Palard X, Edeline J, Ardisson V, Loyer P, Garin E, et al. TransarterialRadioembolization (TARE) agents beyond 90Y-microspheres [internet]. Bio Med Res Int. 2018 [cited 2019 Oct 6]. Available from: https://www.hindawi.com/journals/bmri/2018/1435302/
18. Cappelli A, Pettinato C, Golfieri R. Transarterialra dioembolization using yttrium-90 microspheres in the treatment of hepatocellular carcinoma: a review on clinical utility and developments. J Hepatocell Carcinoma. 2014 Nov 3;1:163–82.
19. Sposito C, Mazzaferro V. The SIRveNIB and SARAH trials, radioembolization vs. sorafenib in advanced HCC patients: reasons for failure, and perspectives for the future. Hepatobiliary Surg Nutr. 2018 Dec;7(6):487–9.
20. Zhang J, Xu F, Chen K, Zhou S, Li H, Niu C, et al. An effective approach for treating unresectable hepatoblastoma in infants and children: preoperative transcatheter arterial chemoembolization. Oncol Lett. 2013 Sep;6(3):850–4.
21. Oue T, et al. Transcatheter arterial chemoembolization in the treatment of hepatoblastoma. 1998 Dec;33(12):1771–5. https://www.ncbi.nlm.nih.gov/pubmed/9869048
22. Arcement CM, Towbin RB, Meza MP, Gerber DA, Kaye RD, Mazariegos GV, et al. Intrahepatic chemoembolization in unresectable pediatric liver malignancies. Pediatr Radiol. 2000 Nov;30(11):779–85.
23. Mahnken A, Pereira P, de Baere T. Interventional oncologic approaches to liver metastases. Radiology. 2013 Feb 1;266:407–30.
24. Gruber-Rouh T, Marko C, Thalhammer A, Nour-Eldin N-E, Langenbach M, Beeres M, et al. Current strategies in interventional oncology of colorectal liver metastases. Br J Radiol. 2016 Aug;89(1064):20151060.
25. Kulkarni S, Shetty NS, Polnaya AM, Patil S, Gala K, Chivate R, et al. Early outcomes of radiofrequency ablation in unresectable metastatic colorectal cancer from a tertiary cancer hospital in India. Indian J Radiol Imaging. 2017;27(2):200–6.
26. de Baere T, Deschamps F, Tselikas L, Ducreux M, Planchard D, Pearson E, et al. GEP-NETS update: interventional radiology: role in the treatment of liver metastases from GEP-NETs. Eur J Endocrinol. 2015 Apr;172(4):R151–66.
27. Gupta S. Intra-arterial liver-directed therapies for neuroendocrine hepatic metastases. Semin Interv Radiol. 2013 Mar;30(1):28–38.
28. Khan W, Sullivan KL, McCann JW, Gonsalves CF, Sato T, Eschelman DJ, et al. Moxifloxacin prophylaxis for chemoembolization or embolization in patients with previous biliary interventions: a pilot study. AJR Am J Roentgenol. 2011 Aug;197(2):W343–5.
29. Gupta S, Johnson MM, Murthy R, Ahrar K, Wallace MJ, Madoff DC, et al. Hepatic arterial embolization and chemoembolization for the treatment of patients with metastatic neuroendocrine tumors: variables affecting response rates and survival. Cancer. 2005 Oct 15;104(8):1590–602.
30. Firouznia K, Ghanaati H, Alavian SM, Nassiri Toosi M, Ebrahimi Daryani N, Jalali AH, et al. Management of liver hemangioma using transcatheter arterial embolization. Hepat Mon. 2014 Dec 25;14(12):e25788.
31. Liu X, Yang Z, Tan H, Huang J, Xu L, Liu L, et al. Long-term result of transcatheter arterial embolization for liver hemangioma. Medicine (Baltimore). 2017 Dec 1;96:e9029.
32. Remiszewski P, Szczerba E, Kalinowski P, Gierej B, Dudek K, Grodzicki M, et al. Epithelioid hemangioendothelioma of the liver as a rare indication for liver transplantation. World J Gastroenterol. 2014 Aug 28;20(32):11333–9.
33. Daller J, Bueno J, Gutierrez J, Dvorchik I, Towbin R, Dickman P, et al. Hepatic hemangioendothelioma: clinical experience and management strategy. J Pediatr Surg. 1999 Feb 1;34:98–105.

13 Interventions for Portal Hypertension: Hepatic Vein Pressure Gradient and Trans Jugular Liver Biopsy

Vinu Moses and Shyamkumar N. Keshava

13.1 Hepatic Vein Pressure Gradient

13.1.1 Introduction

Hepatic vein pressure gradient (HVPG) measurement for the quantification of portal hypertension is considered the gold standard for the measurement of portal pressure. It is defined as the difference in pressures between the occluded and free hepatic vein. The pressure in the occluded hepatic vein represents the hepatic sinusoidal pressure, which is slightly lower than the portal pressure. This difference in pressure is however clinically insignificant. Measurement of the HPVG is used to quantify the degree of portal hypertension in chronic liver disease. Normal HPVG values are between 1 to 5 mmHg. Higher pressures are considered to represent portal hypertension. Pressures greater than 10 mmHg represent clinically significant hypertension, while pressures above 12 mmHg increase the risk of variceal rupture [1, 2].

Indications

1. Confirmation of portal hypertension: HVPG is considered to be the gold standard for the confirmation of portal hypertension as it measures actual pressures in the liver.
2. To assess the temporal evolution of chronic liver disease: Serial HPVG measurements can be used to objectively assess the disease progression in chronic liver disease.
3. Stratify risk of variceal bleeding: Pressure measurements above 12 mmHg have been associated with increased risk of variceal rupture and patients with pressures over 20 mmHg have a higher risk of failure to control bleeding and greater mortality [3].
4. To assess treatment efficacy of medical management of portal hypertension: Reduction of portal pressures with beta-blockers to <10 mmHg reduces the likelihood of new varices forming in a person who does not have preexisting varices and reduction of portal pressures <12 mmHg in a person with preexisting varices reduces the risk of bleeding of these varices significantly [4].
5. To quantify preoperative risk for patients with cirrhosis: Studies have shown that cirrhotic patients have higher procedural and post-procedural morbidity and mortality, even for elective surgery [5].

Contraindications

1. History of allergy to iodinated IV contrast media: This is a relative contraindication as carbon dioxide can be used as a substitute contrast media in these cases.

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2. Budd–Chiari syndrome (BCS) with occlusion of all three hepatic veins: Hepatic venous pressure measurements cannot be taken in patients with BCS involving all three hepatic veins. Direct wedge pressure from the intrahepatic IVC has been described but has not been standardized for routine clinical use.
3. Bilateral jugular venous thrombosis: Occlusion or thrombosis of bilateral internal jugular veins is a relative contraindication. Catheterization of the hepatic veins through the trans-femoral venous route can be done but is technically more challenging.
4. Severely deranged bleeding parameters (Prothrombin Time (PT) International Normalised Ratio (INR) > 2.5 or Activated Partial Thromboplasin Time (APTT) > 40 or Platelets <40,000/cu.mm).

13.1.2 Procedural Technique

Informed consent should be obtained from the patient. The procedure carries no significant risk, other than the regular risks of vascular access.

13.1.3 Steps of Procedure

1. Patient may be given a sedative and anxiolytic 30 min before procedure.
2. Patient is placed in supine posture on the DSA gantry. The operator stands at the head end of the patient.
3. Site of venous access—right side of the neck/right groin is painted and draped with sterile precautions.
4. Right internal jugular venous (IJV) access is preferred to the left side, owing to its shorter and straighter course to the liver. Alternatively right femoral venous access may also be taken.
5. After infiltration of local anaesthetic, ultrasound-guided puncture of the IJV is done and the vascular access is secured with a short 9F vascular sheath.
6. Pressure measurement of the right atrium is done with a pressure transducer. Visualisation of normal cardiac waveforms on the pressure monitor display corroborates the veracity of the measurement.
7. Under fluoroscopy, the hepatic vein is catheterized with a combination of a 4F or 5F multipurpose catheter (Cook, Bloomington, US) and a 035″ angled glide wire (Terumo, Japan) (Fig. 13.1).
8. If all hepatic veins are patent, the right hepatic vein is preferred as it has a relatively straighter course and least acute angulation when accessed from the IVC along the trans jugular route.
9. A hepatic venogram is done to confirm the position of the catheter in the hepatic vein.
10. The free hepatic venous pressure is measured from the catheter tip that is placed 2–4 cm from the ostium of the hepatic vein [1]. Normal cardiac waveforms (a and v waves) are usually visualized on the pressure monitor display.
11. Wedged hepatic pressure can then be taken in two ways:
    (a) Catheter wedge: The multipurpose catheter is wedged into the liver parenchyma or a small branch of the hepatic vein (Fig. 13.2), till the normal waveform (a and v waves) that are visualized on the pressure monitory display disappears. A pressure reading is noted once the pressure readings are stable.
    (b) Balloon wedge: The multipurpose catheter is exchanged for a compliant occlusion balloon. The balloon is inflated in the hepatic vein (Fig. 13.3) and the pressure through the central lumen (wire lumen) is measured after removing the wire.
12. The difference between the wedged hepatic venous and free hepatic venous pressures are calculated.
13. The catheter/balloon is removed and the venous access is removed. Patient is kept in a semi-erect or supine position for a few hours to reduce the risk of access site bleeding.
14. Patient is usually admitted in day care and can be discharged 3–6 h after the procedure.

13.1.4 Complications

The complications (though rarely seen), are mostly related to vascular access and comprises of bleeding, hematoma, dissection, thrombosis, and fistula formation. Horner's syndrome is a rare complication. Supraventricular tachycardia can occur during passage or manipulation of the catheter and wire through the right atrium [1].

13.1.5 Discussion

HVPG measurement is a safe test to perform and a number of studies have shown its safety and low complication rates [6, 7] both in children and adults.

The original description of the measurement of HVPG used a balloon to measure hepatic wedge pressure. The technical modification of using just a catheter to wedge is simpler to perform, has a lesser risk of complications like subintimal injury associated with the inflation of the balloon, lesser radiation exposure, and has also been validated to have similar accuracy of measurements when compared with the balloon wedge technique [8].

Measurement of HVPG is considered the gold standard for measurement of portal pressures. As the measurement of HVPG is an invasive procedure, a number of noninvasive methods have been evaluated to assess the severity of portal hypertension including indices based on liver function tests, biochemical markers, liver stiffness by ultrasound elastography, splenic elastography, and MR elastography of the liver [3, 9].

Liver elastography has been shown to correlate clinically with the degree of liver fibrosis and also portal pressures. Early studies using transient elastography are less accurate but shear wave elastography using Acoustic Radiation Force Impulse (ARFI) is able to reliably diagnose significant portal hypertension with sensitivity and specificity values of over 80–90% in various studies [10].

Spleen elastography studies to see if splenic stiffness correlates with portal hypertension have shown good sensitivity but less specificity [11]. Some have suggested that a combination of liver and spleen stiffness to better improve the sensitivity and specificity of both tests.

MR elastography has been studied to assess the correlation between cirrhosis and portal pressures. However, this is still in research and is not widely used [12, 13].

13.1.6 Conclusion

In summary, HVPG is still considered the gold standard test for obtaining the most accurate reflection of portal pressure measurements.

13.2 Trans Jugular Liver Biopsy

13.2.1 Introduction

Trans jugular liver biopsy (TJLB) is a method of obtaining liver tissue for histology when there is a contraindication for doing a percutaneous liver biopsy. TJLB is usually done for diffuse liver disease and not focal liver lesions [14].

13.2.2 Indications

The common indications of TJLB are

1. Significant ascites: Minimal ascites that is not distributed around the liver is not a contraindication for a percutaneous liver biopsy.
2. Coagulopathy: Deranged Prothrombin time (INR > 1.6), Activated Partial Thromboplastic Time and low platelets (< 40,000/cu.mm) are indications for a TJLB.
3. Chronic renal failure: High uremic levels cause platelet dysfunction, and this can cause prolongation of bleeding time.
4. Shrunken liver: If the liver cannot be well visualized on ultrasound for a percutaneous liver biopsy, a TJLB can be considered.
5. Hereditary hemorrhagic telangiectasia, peliosis hepatis, morbid obesity, and suspected amyloidosis: These patients have an increased risk of bleeding.

Contraindications

1. Grossly deranged bleeding parameters that are not correctable.
2. Thrombosis of bilateral internal jugular veins: External jugular veins or femoral access can be attempted in these patients but are technically more challenging.

13.2.3 Procedural Technique [15]

Materials: (a) Angiography suite with an ultrasound machine; (b) a TJLB set (LABS-100, Cook), 9F short sheath, multipurpose catheter, 035″ "j" tip guide-wire and angled glide wires.

Patient preparation: TJLB is an inpatient procedure. Ultrasound of the liver is done before the procedure to confirm patency of internal jugular vein, diffuse nature of liver disease, and patency of hepatic veins. Patient is kept fasting for 6 h before procedure to reduce the risk of aspiration. Patient may be given an anxiolytic 30 min before procedure or the procedure may be performed under conscious sedation.

13.2.4 Steps of Procedure

1. Patient is placed supine on the DSA gantry. The operator stands at the head end of the patient.
2. Patient is monitored for oxygen saturation, pulse, and blood pressure during the procedure.
3. Site of venous access—right or left side of neck is painted and draped with sterile precautions.
4. Right internal jugular venous (IJV) access is preferred, owing to its shorter and straighter course to the liver.
5. After infiltration of local anesthetic, ultrasound guided single wall puncture of the IJV is done in the mid neck with a 18G needle and a short 9F vascular sheath is inserted.
6. A combination of a 035″ guidewire and multipurpose catheter are used to navigate from the IJV through the right atrium into the IVC and the hepatic vein.
7. If all hepatic veins are patent, the right hepatic vein is preferred as it has a relatively straighter course and least acute angulation when accessed from the IVC along the trans jugular route.
8. A hepatic venogram is done to confirm the position of the catheter in the hepatic vein.
9. The catheter is exchanged over a wire for a TJLB stiff cannula. The tip of the cannula should be positioned 2–3 cm into the liver from the hepatic ostium.
10. The TruCut biopsy needle (available in the TJLB set) is prepared and taken up to the tip of the stiff TJLB cannula under fluoroscopy.
11. With the patient holding his breath, the stiff cannula is turned (anteriorly if in the right hepatic vein and to the right if in the middle hepatic vein) to wedge it into the parenchyma, the TruCut biopsy needle is pushed a centimeter outside the stiff cannula, fired and quickly withdrawn back into the stiff cannula. The patient is then asked to resume breathing. This step should be done in 10–15 seconds.
12. The TruCut needle is withdrawn from the stiff cannula and the specimen is retrieved.
13. Usually, 2–3 passes are made for the collection of samples for histopathology and dry weight. For suspected infections, a sample is also taken for culture.
14. A check hepatic venogram is done after the biopsy to exclude contrast extravasation.
15. The stiff cannula is withdrawn and the jugular venous access is secured with compression.
16. The patient is asked to sit up after the procedure in bed for a few hours to reduce the risk of hematoma formation in the jugular puncture site.
17. The patient is kept in the hospital for a day, to rule out any hepatic bleeding.

The technique for catheterization of the hepatic veins and doing the liver biopsy is covered in extensive detail in literature [15].

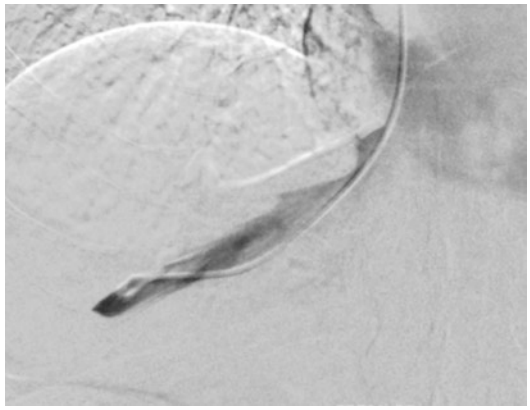

Fig. 13.1 Hepatic venogram to confirm position of catheter in right hepatic vein

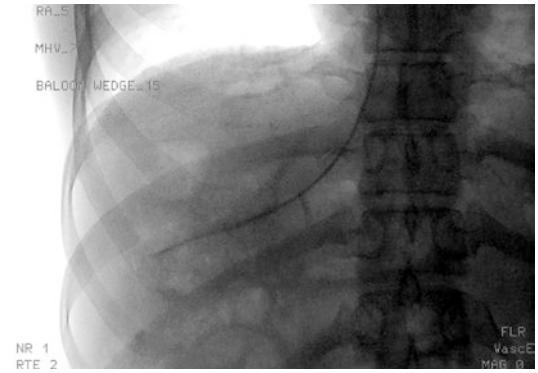

Fig. 13.2 Hepatic wedge pressure measured by wedging the catheter in the hepatic vein

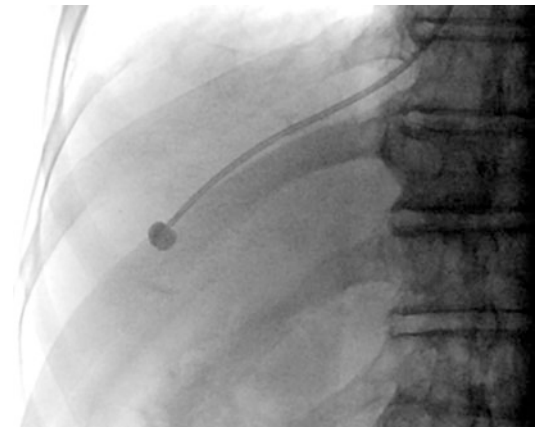

Fig. 13.3 Hepatic wedge pressure measured by wedging a balloon catheter in the hepatic vein

13.2.5 Complications

The complications, which are rarely seen, are mostly related to local vascular access (bleeding, hematoma, dissection, thrombosis, and fistula formation). Horner's syndrome is a rare complication. Supraventricular tachycardia can occur during passage or manipulation of the catheter and wire through the right atrium and is usually transient [1]. Pneumothorax can occur if there is accidental perforation of the apical pleura during vascular access.

Hepatic complications are rarer and include trans-capsular perforation with hemoperitoneum and hepatobiliary injury causing haemobilia or arteriovenous fistula formation.

TJLB is described to have a minor complications rate of 5–20% and a 1–2% major complication rate (SIR complications criteria) [14, 16].

13.2.6 Discussion

TJLB is a safe and established procedure for obtaining liver biopsies.

There have been numerous technical modifications to the equipment and procedure over time. When first described, the procedure used a punch biopsy technique, but this has been superseded by semiautomatic the TruCut biopsy which gives longer and less fragmented cores of tissue. Adequate histologic specimen is described as a specimen that is either 15 mm in length or contains atleast 6 complete portal tracts. Studies have described a very high histologic success rate of 98.5% for the procedure [14, 17] (Figs. 13.2 and 13.3).

When the hepatic vein is difficult to cannulate or in a patient with Budd–Chiari syndrome, direct trans-caval biopsy of the liver can be done under fluoroscopy and the US guidance [18]. If the internal jugular veins are not accessible or if the hepatic veins cannot be catheterised through the trans jugular route, a transfemoral venous approach has also been described [19].

In patients with only deranged bleeding parameters but no ascites, plugged percutaneous liver biopsy has been shown to have similar risks and complications as TJLB. However, in patients with

grossly deranged bleeding parameters, TJLB may still be a safer alternative as any bleeding that occurs happens within the vascular tree. Plugged liver biopsy provides a better specimen as the gauge of the biopsy needle is larger [20, 21].

As TJLB is a short procedure with short fluoroscopy times (3–6 min), the radiation exposure for a TJLB is also low, ranging from 0.5 to 1 mSv [14].

13.2.7 Conclusion

TJLB is a safe procedure with a high technical success rate, low complication profile, and low radiation exposure.

References

1. Abraldes JG, Sarlieve P, Tandon P. Measurement of portal pressure. Clin Liver Dis. 2014 Nov;18(4):779–92.
2. Kumar A, Sharma P, Sarin SK. Hepatic venous pressure gradient measurement: time to learn! Indian J Gastroenterol. 2008 Apr;27(2):74–80.
3. Procopeţ B, Tantau M, Bureau C. Are there any alternative methods to hepatic venous pressure gradient in portal hypertension assessment? J Gastrointestin Liver Dis. 2013 Mar;22(1):73–8.
4. Reiberger T, Ulbrich G, Ferlitsch A, et al. Carvedilol for primary prophylaxis of variceal bleeding in cirrhotic patients with hemodynamic nonresponse to propranolol. Hepatology. 2012;56(S1):272A–3A.
5. Lovet JM, Bruix J, Fuster J, et al. Liver transplantation for small hepatocellular carcinoma: the tumor-node-metastasis classification does not have prognosis power. Hepatology. 1998;27:1572–7.
6. Woolfson J, John P, Kamath B, Ng VL, Ling SC. Measurement of hepatic venous pressure gradient is feasible and safe in children. J Pediatr Gastroenterol Nutr. 2013 Nov;57(5):634–7.
7. Stift J, Semmler G, Walzel C, Mandorfer M, Schwarzer R, Schwabl P, et al. Transjugular aspiration liver biopsy performed by hepatologists trained in HVPG measurements is safe and provides important diagnostic information. Dig Liver Dis. 2019 Aug;51(8):1144–51.
8. Chelliah ST, Keshava SN, Moses V, Surendrababu NRS, Zachariah UG, Eapen CE. Measurement of hepatic venous pressure gradient revisited: catheter wedge vs balloon wedge techniques. Indian J Radiol Imaging. 2011;21:291–3.
9. Karagiannakis DS, Voulgaris T, Siakavellas SI, Papatheodoridis GV, Vlachogiannakos J. Evaluation of portal hypertension in the cirrhotic patient: hepatic vein pressure gradient and beyond. Scand J Gastroenterol. 2018 Nov;53(10–11):1153–64.
10. Elkrief L, Rautou PE, Ronot M, et al. Prospective comparison of spleen and liver stiffness by using shear-wave and transient elastography for detection of portal hypertension in cirrhosis. Radiology. 2015;275:589–98.
11. Ma X, Wang L, Wu H, et al. Spleen stiffness is superior to liver stiffness for predicting esophageal varices in chronic liver disease: a meta-analysis. PLoS One. 2016;11:e0165786.
12. Yin M, Glaser KJ, Manduca A, Mounajjed T, Malhi H, Simonetto DA, et al. Distinguishing between hepatic inflammation and fibrosis with MR Elastography. Radiology. 2017;284(3):694–705.
13. Petitclerc L, Sebastiani G, Gilbert G, Cloutier G, Tang A. Liver fibrosis: review of current imaging and MRI quantification techniques. J Magn Reson Imaging. 2017;45(5):1276–95.
14. Mammen T, Keshava SN, Eapen CE, Raghuram L, Moses V, Gopi K, et al. Transjugular liver biopsy: a retrospective analysis of 601 cases. J Vasc Interv Radiol. 2008 Mar;19(3):351–8.
15. Keshava SN, Mammen T, Surendrababu N, Moses V. Transjugular liver biopsy: what to do and what not to do. Indian J Radiol Imaging. 2008 Aug;18(3):245–8.
16. Dohan A, Guerrache Y, Dautry R, Boudiaf M, Ledref O, Sirol M, et al. Major complications due to transjugular liver biopsy: incidence, management and outcome. Diagn Interv Imaging. 2015 Jun;96(6):571–7.
17. Cholongitas E, Quaglia A, Samonakis D, Senzolo M, Triantos C, Patch D, et al. Transjugular liver biopsy: how good is it for accurate histological interpretation? Gut. 2006 Dec;55(12):1789–94.
18. Moses V, Keshava SN, Mammen S, Ahmed M, Eapen CE, Ramakrishna B. Trans-caval trans-jugular liver biopsy--a technical modification of trans-jugular liver biopsy. Br J Radiol. 2014 Nov;87(1043):20140327.
19. Khosa F, McNulty JG, Hickey N, O'Brien P, Tobin A, Noonan N, et al. Transvenous liver biopsy via the femoral vein. Clin Radiol. 2003 Jun;58(6):487–91.
20. Atar E, Ben Ari Z, Bachar GN, Amlinski Y, Neyman C, Knizhnik M, et al. A comparison of transjugular and plugged-percutaneous liver biopsy in patients with contraindications to ordinary percutaneous liver biopsy and an "in-house" protocol for selecting the procedure of choice. Cardiovasc Intervent Radiol. 2010 Jun;33(3):560–4.
21. Tsang WK, Luk WH, Lo AXN. Ultrasound-guided plugged percutaneous biopsy of solid organs in patients with bleeding tendencies. Hong Kong Med J. 2014 Apr;20(2):107–12.

14 Interventions for Portal Hypertension: Trans Jugular Intrahepatic Portosystemic Shunts (TIPS)

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14.1 Introduction

The concept of Transjugular intrahepatic portosystemic shunt (TIPS) was introduced in the 1960s by accidental access of the portal system during trans jugular attempt at performing cholangiography [1]. This was followed by animal experiments and tract dilatation [2]. The procedure gained acceptance in the 1990s after the introduction of dedicated covered stents to keep the tract patent [3]. In the era of liver transplantation, an intrahepatic TIPS stent has an advantage over surgically created extrahepatic shunts, as the stent will be removed along with the explanted liver at the time of the transplant [4]. TIPS is considered as one of the most challenging interventional radiology procedure. The key step is the creation of the tract between the hepatic vein and the portal vein, which determines the outcome of the procedure, including the success, complications, duration of the procedure, and the radiation. The creation of the shunt is conventionally undertaken with fluoroscopy. To improve the successful creation of the shunt, one needs to know the anatomical relation between the hepatic and portal vein. This needs to be studied with cross-sectional imaging modalities like CECT. Several technical modifications have been introduced by various investigators including carbon dioxide wedge portography, intravascular ultrasound, transabdominal ultrasound, CT scan, etc. This additional guidance reduces the number of punctures to create the shunt and improves precise intrahepatic localization of the portal vein, thus reducing the duration of the procedure. It also improves safety by reducing the chance of inadvertently injuring the liver capsule, hepatic artery, gall bladder, etc. Reduction in the fluoroscopy duration also has been achieved by techniques like additional transabdominal ultrasound guidance [5].

Among the guidelines, the American Association for the Study of Liver Diseases (AASLD; updated in 2009) recommendations are the most widely practiced. The guidelines address both clinical and anatomical suitability in the patients of portal hypertension. Failure of endoscopic procedures in acute gastroesophageal variceal hemorrhage, refractory gastroesophageal variceal bleeding, and refractory ascites secondary to portal hypertension are the common established indications [6].

14.2 Indication and Contraindication

TIPS is often considered as a last resort to treat complication of PHT in cirrhosis when conservative medical and endoscopic procedures have

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Table 14.1 Indications for TIPS [references: 6–26]

Secondary prophylaxis of variceal bleeding
Refractory ascites
Acute variceal bleeding
Hepatic hydrothorax
Hepatorenal syndrome
Hepatopulmonary syndrome
Portal vein thrombosis
Budd–Chiari syndrome
Hepatic veno-occlusive disease
Portal gastropathy

failed. Secondary prophylaxis of gastroesophageal variceal bleeding and refractory ascites are the two most common indications for TIPS with strong clinical evidence available in the literature. TIPS for many other indications are still evolving. Some of the contraindications classified as relative contraindications such as portal vein thrombosis and occlusion of all hepatic veins in the 2009 American association for the study of liver disease (AASLD) practice guidelines have become indications for the TIPS (Table 14.1).

Studies have shown that early use of TIPS in acute gastroesophageal and other variceal bleeding is associated with lower rates of rebleeding and higher patient survival compared to medical and endoscopic treatment [8–10]. A meta-analysis of nine randomized controlled trials comparing early TIPS and endoscopic treatment for secondary prophylaxis of esophageal variceal bleeding revealed, at 1 year, significant difference in mortality (16.9% in early TIPS and 24.5% endoscopic group; $P = 0.03$) and rebleeding of varices (13% in early TIPS and 46.5% in endoscopic group; $P < 0.01$) and no significant difference in incidence of encephalopathy (29% in early TIPS and 23% in endoscopic groups; $P = 0.34$) [11].

Various retrospective studies have shown promising results of TIPS for hepatic hydrothorax. Improvement of symptoms was seen in 68–80% and complete response in 58–71% of patients [12–15].

In BCS, anticoagulation and if feasible recanalization of the obstructed hepatic vein or IVC to improve hepatic outflow is the first choice of treatment. TIPS is usually considered when first line treatment fails in the management of the complications of PHT [6, 16–18]. TIPS can be created directly between the IVC and PV if hepatic veins are occluded [DIPS, direct intrahepatic portosystemic shunt] or through a stent in the hepatic vein or IVC [19–21].

TIPS in portal vein thrombosis is indicated when there is rapid clinical deterioration due to acute liver failure or high risk of bowel gangrene [22]. TIPS can be performed in chronic portal vein thrombosis with cavernoma formation resulting in gastric or esophageal varices with high risk of bleeding on anticoagulation and when there are deranged coagulation and low platelets. Results of a recent meta-analysis show that TIPS is feasible in PVT with good 1 year shunt patency and survival rate [23]. Chronic PVT with cavernoma formation poses technical difficulty for shunt creation; however, TIPS can be done if suitable PV is available for the stent placement. In acute PVT, the objective is to remove the thrombus and decompress the portal system. However, TIPS is associated with more complications when it is combined with thrombolysis [23].

TIPS is indicated in selected patients of hepatorenal syndrome (Type-2 Hepatorenal syndrome) not responding to medical treatment. Many studies and meta-analysis have shown TIPS in hepatorenal syndrome improve renal function in 83% of patients with improved serum creatinine, blood urea nitrogen level, urine output, and urine sodium excretion [24].

TIPS in hepatopulmonary syndrome improves oxygenation in most of the patients. It can be done either as a primary indication or as a bridge to liver transplant. The available evidence is only limited to small observational studies and meta-analysis of case reports and case series [25, 26].

Rarely, TIPS may be required while occluding congenital large portocaval shunts if there is a potential risk of acute portal hypertension.

Most of the contraindications are relative except active systemic infection or sepsis, unrelieved biliary obstruction, severe heart failure, and pulmonary arterial hypertension [6]. TIPS

Table 14.2 Contraindications for TIPS [6, 7, 27, 28]

Absolute contraindication
1. Primary prevention of variceal bleeding
2. Sepsis or active systemic infection
3. Severe liver failure
4. Severe pulmonary arterial hypertension (mean > 45 mmHg)
5. Severe congestive heart failure or tricuspid regurgitation
6. Unrelieved biliary obstruction
Relative contraindication:
1. Polycystic kidney disease
2. Deranged coagulation
3. Moderate pulmonary arterial hypertension
4. Extensive or central hepatocellular carcinoma
5. Recurrent or severe hepatic encephalopathy
6. Hepatic artery or celiac artery stenosis (reduced liver perfusion)

can be done electively after control of the infection in sepsis and after treating unrelieved biliary obstruction. TIPS can still be done in selected cases in severe liver failure (MELD>15–18, serum bilirubin >4 mg/dl, Child Pugh >13) if there is no other treatment option [27]. The selection of patients is always a multidisciplinary, consensus decision and is based on risk versus benefits. Often, the benefits of TIPS in the presence of contraindications can exceed its associated risks (Table 14.2).

14.3 Technique

14.3.1 Pre-Procedure Work Up

Preprocedural lab investigations should be obtained to assess liver, renal, and cardiac functions including bilirubin, albumin, liver enzymes, coagulation profile, serum creatinine, blood urea nitrogen, serum electrolytes, ECG, and echocardiography.

Cross-sectional imaging, preferably contrast-enhanced CT scan is very useful for the study of vascular anatomy of the liver before TIPS. It is important to know intrahepatic or extrahepatic location and patency of the portal vein bifurcation as access to extrahepatic portal vein branch can cause severe intraperitoneal hemorrhage. Preprocedural antibiotic coverage is optional.

14.3.2 Conventional Technique of TIPS

In the creation of portosystemic shunt, the most important and time consuming step is the access of PV from hepatic vein or IVC. Portal vein access is followed by the standard technique of parenchymal tract dilatation with balloon plasty and stent graft placement. Conventional technique (Fig. 14.1) of PV access includes indirect visualization of the portal veins under fluoroscopy with intra-arterial injection of iodinated contrast into the celiac or superior mesenteric artery. Alternatively, CO2 or iodinated contrast portogram with a transjugular catheter wedged against liver parenchyma in a hepatic vein or with a balloon occluding hepatic vein can be performed to demonstrate portal vein. This is then followed by puncture of a suitable portal vein under fluoroscopic guidance. Direct portal venography has also been described where portal venography is done after percutaneous transhepatic PV puncture or cannulation of PV through a recanalized paraumbilical vein [29, 30].

14.3.3 Standard of Practice of Performing TIPS by the Authors

TIPS is performed as in-patient procedure. It may be performed under conscious sedation and monitoring or under general anesthesia.

The procedure is performed by a team of 2 to 3 members. The operator(s) standing on the head-side of the patient works through the transjugular access. The operator performing the transabdominal ultrasound would stand on the right side of the patient. The USG equipment is placed in between, on the right side of the patient, so that it is visible to everyone.

The authors use RUPS-100 (Rosch-Uchida trans jugular liver access set, Cook medical) set for creating TIPS (Table 14.3. and Fig. 14.2). Following are the steps of the procedure (Fig. 14.2);

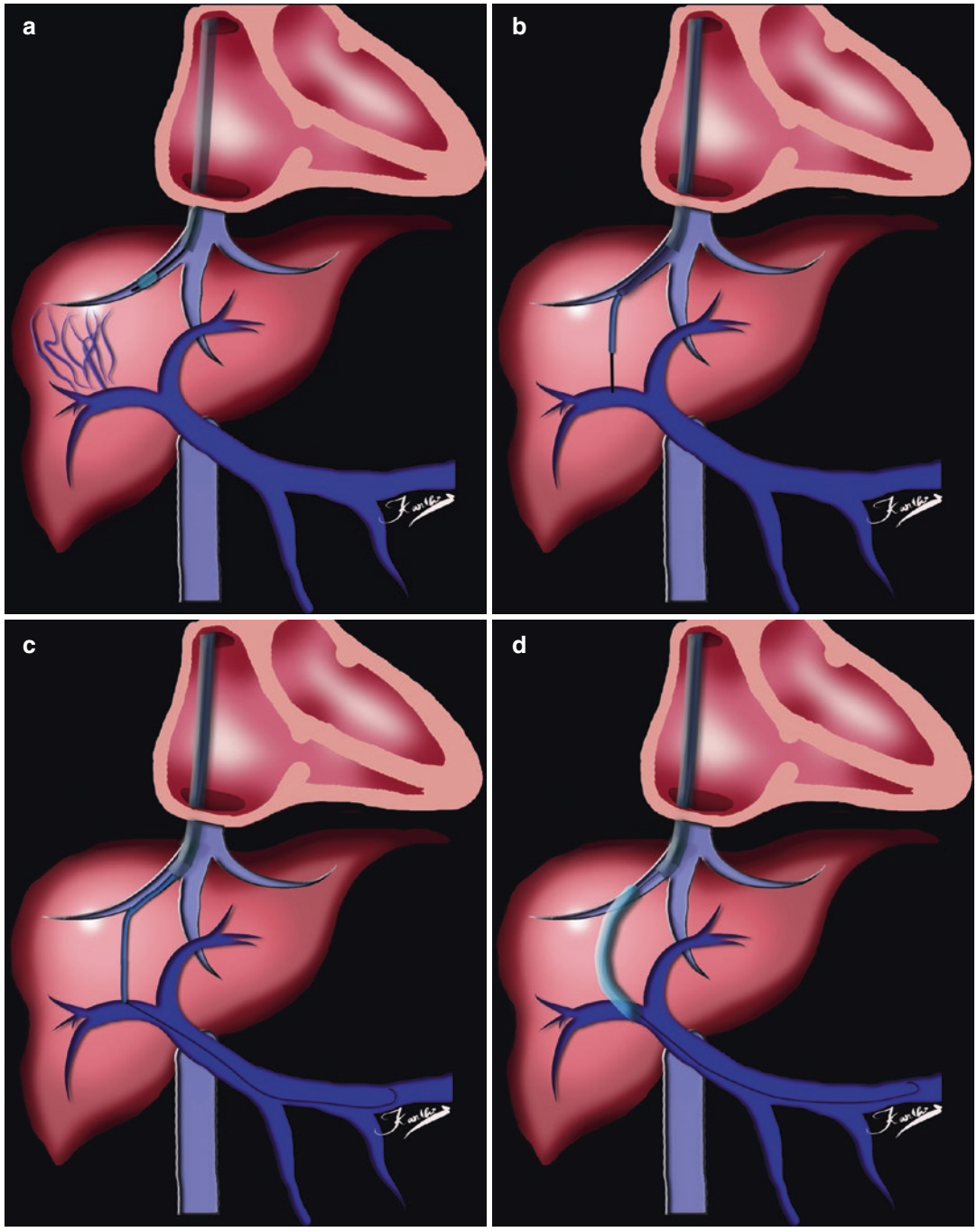

Fig. 14.1 Diagrammatic representation of conventional technique of TIPS; (**a**) Portogram with a balloon catheter wedged in the hepatic vein, (**b**) Puncture of the portal vein under fluoroscopy guidance. (**c**) 4/5F catheter with guidewire in the portal vein. (**d**) Balloon plasty of the parenchymal tract. (**e**) Stent placement after balloon plasty

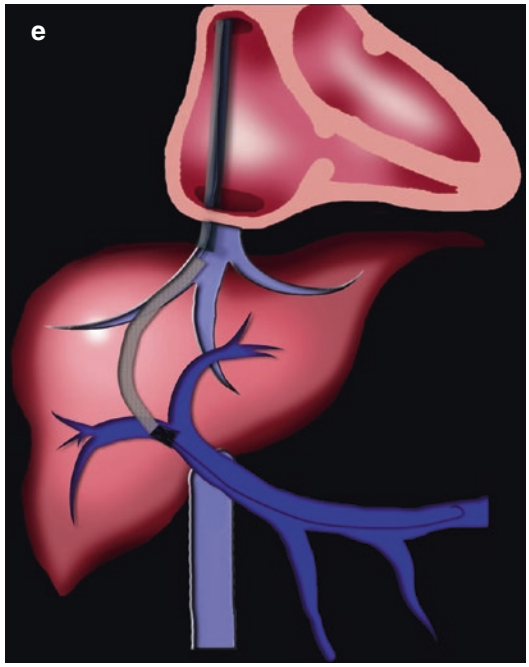

Fig. 14.1 (continued)

Table 14.3 Hardwares needed for TIPS

1. RUPS-100 (Rosch-Uchida transjugular liver access set, cook medical). It consists of the following items: a. Blue catheter with 0.038 in flexible trocar stylet b. Stiffening cannula with PTFE catheter c. Flexor check-flo introduce sheath with dilator
2. Short introducer sheath 5/6F
3. Standard J tip guidewire 0.035″, 160–180 cm
4. Hydrophilic catheter 65 cm, 4F
5. Hydrophilic guidewire 0.035″, 180 cm
6. Marker pigtail catheter 5F, 100 cm
7. Low profile balloon, 035inch compatible, 4 to 10 mm diameter, 4–6 cm
8. Covered stents preferably standard dedicated TIPS stent

1. Access is secured in the right internal jugular vein under USG guidance with a 5F short sheath. A cavogram is performed in the IVC and pressures in the right atrium and IVC are documented.
2. The hepatic vein which is closest to, and preferably behind the portal vein is cannulated with a 4/5F multipurpose catheter and a 0.035″, 180 cm Amplatz wire (Cook medical) is placed in the hepatic vein. The 5 Fr sheath is then exchanged for a 10F, 40 cm long introducer sheath with a stiffening cannula over the Amplatz wire into the hepatic vein [the stiffening cannula must be given an adequate bend distally to allow it to wedge against the liver parenchyma]. After removing the Amplatz guidewire, a needle is inserted upto the tip of the cannula.
3. Under transabdominal USG guidance, the trajectory of the needle from hepatic vein or IVC is determined to target an intrahepatic portal vein branch. This portal branch should be intrahepatic, preferably the right branch of the portal vein and approximately 1 cm or more from the confluence of the main portal vein. The cannula is wedged against the hepatic parenchyma and held in a stable position as it moves back while the needle is thrust into the liver parenchyma. The cannula position may be changed in such a way that the planned tract is short. If needed, the cannula may be pulled out over a guidewire, the curvature manually adjusted and reinserted. The needle (blue catheter with 0.38 inch trocar stylet) is advanced toward the target PV branch and the PV has punctured under real-time transabdominal USG guidance. The puncture of the portal vein should be "single-walled," i. e., the wall close to the cannula while avoiding overshooting the needle and puncturing the liver capsule.
4. After PV puncture, a syringe is connected to the blue catheter and aspirated for portal blood while very slowly withdrawing the catheter. Contrast portography is avoided to prevent microbubble injection near the tract, which could reduce the visibility on USG if further punctures are required. A stiff hydrophilic 0.035″ glide wire is advanced through the blue catheter after removing the needle (0.38″ trocar stylet) either under USG or fluoroscopic guidance. The Guidewire is sufficiently advanced into the superior mesenteric (SMV) or splenic vein (SV). Needle blue catheter is removed and a 4F cobra glide catheter is advanced over the glide wire into SMV or SV. A 0.035″ exchange length stiff guidewire is passed through the catheter. The catheter and the cannula are removed. A 5F marker pigtail is advanced over

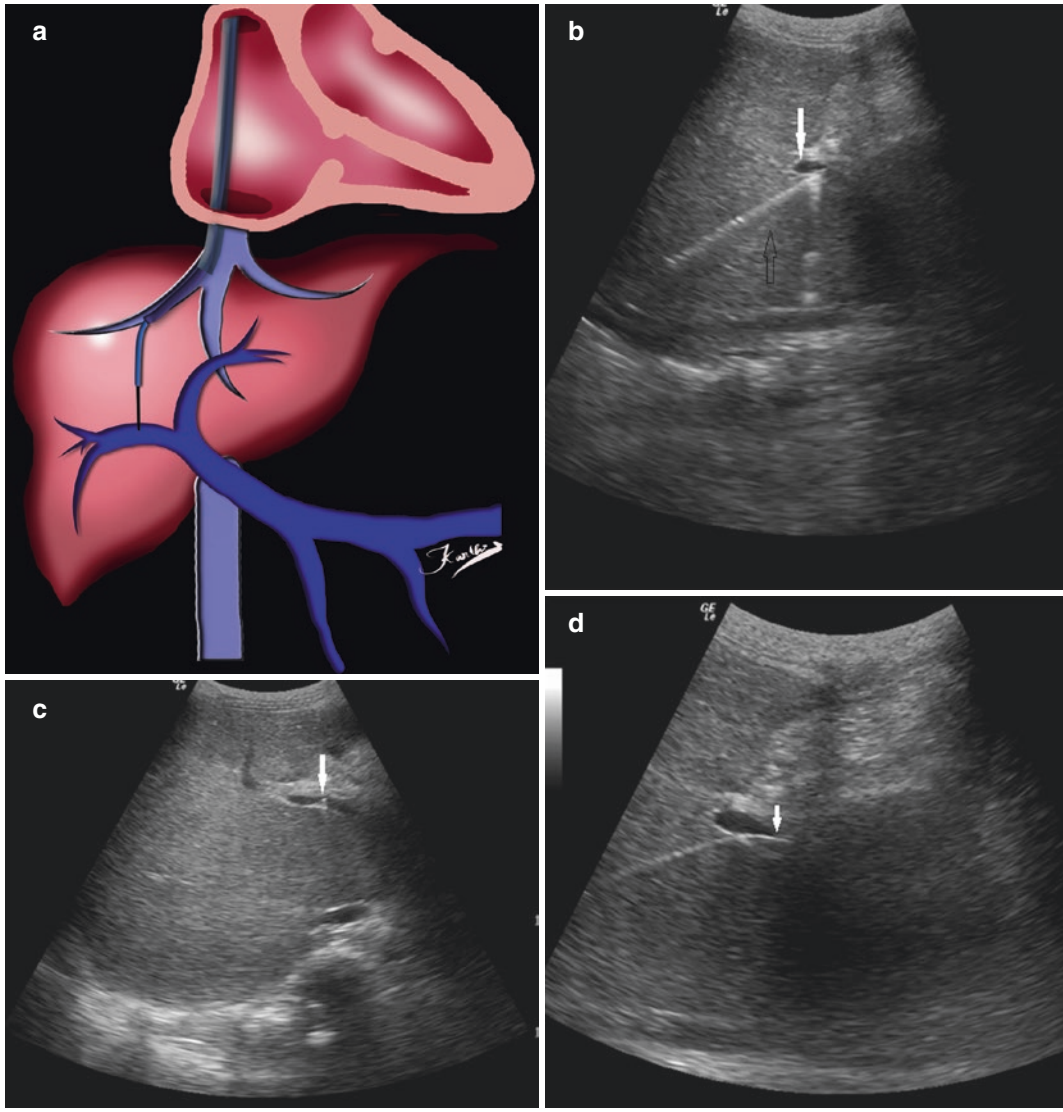

Fig. 14.2 TIPS under per abdomen USG and fluoroscopy guidance. (**a**) Diagrammatic representation showing puncture of the portal vein branch under per abdomen USG guidance (**b**) Per abdomen USG guidance image showing needle advancement and puncture of the portal vein branch. (**c** and **d**) USG images showing hydrophilic wire in the portal vein. (**e**) Portogram after puncture of the portal vein, (**f**) Stent deployed after balloon plasty. (**g**) Final portogram after post-stent plasty

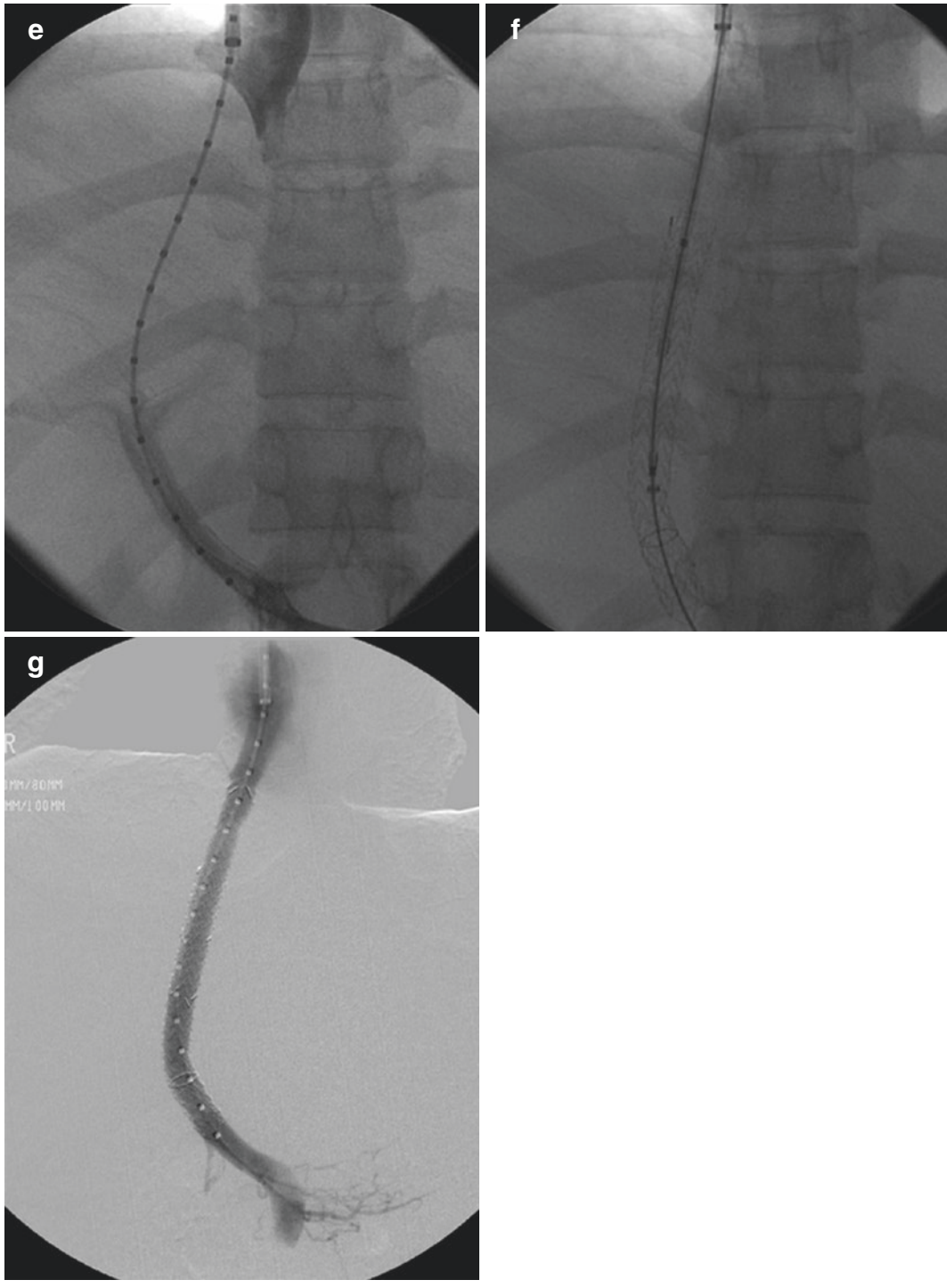

Fig. 14.2 (continued)

the guidewire into the main portal vein. In case of difficulty in advancing pigtail catheter at PV entry site, the tract can be dilated with a 4mmx4cm balloon catheter. Heparin 5000 units bolus is injected at this time.

5. Portogram is obtained by injecting contrast preferably with a breath hold. Simultaneous IVC-grams are also obtained. The site of entry into the portal system, length of the tract, size of the portal vein, and collateral flow from the portal system are noted. Portal pressures are also documented to obtain the pressure gradient.

   The exchange length 0.035″ guidewire is reinserted. The parenchymal tract is dilated with an 8 or 10 mm balloon, of the length of 4 cms. The length of the TIPS stent graft is selected based on the simultaneous portogram with marker pigtail catheter and inferior vena cavogram with introducer sheath. The introducer sheath with the dilator is advanced into the portal vein prior to stent graft placement. Stent graft is then deployed with the covered portion just extending (5–10 mm) within the PV branch inferiorly and to IVC superiorly.
6. The procedure is completed with portal and right atrial pressure measurement and portogram. Portal pressure gradient (PPG) of 12 mm Hg or less should be achieved for adequate control of the complications of PHT.
7. Immediate post-procedure care: The patient is monitored in ICU or HDU for 24 h.

   The patency of the shunt should be checked on color Doppler USG at 48 h and subsequently on follow-up at 1, 3, and 6 months and after every 6 months. Catheter venogram and pressure gradient measurements should be obtained on suspicion of shunt stenosis on color Doppler USG or clinical recurrence or worsening. Patients with Budd–Chiari syndrome are put on life-long anticoagulant maintaining INR between 2 and 3.

14.3.4 TIPS in BCS

TIPS in Budd–Chiari syndrome is technically challenging due to occlusion of hepatic veins or IVC. PV can be accessed directly from the intrahepatic IVC at or just below the expected hepatic vein confluence (direct intrahepatic portosystemic shunt, DIPS). The PV can also be accessed through the IVC stent or occluded hepatic vein stent and TIPS stent graft can be placed after serial dilatation of the stent strut (strut plasty) (Fig. 14.3) [20, 21].

14.4 Technical Modifications

In an effort to increase accuracy, many other techniques have been used which differ in their image guidance and techniques to access PV [29, 30].

14.4.1 IVUS as Additional Guidance during Tract Creation

Intravascular US was used by Farsad et al., [30] which was described as a safe and effective way of real-time image guidance for TIPS creation. The authors also described the additional advantages for cases like PV thrombus, distorted anatomy, Budd–Chiari syndrome, or hepatic tumors. The IVUS is placed in IVC through femoral venous access.

14.4.2 Gun-Sight Technique

Gun-sight technique is a percutaneous technique, an alternative technique described when conventional techniques are less likely to work. The shunt is created with a percutaneous transhepatic approach across a suitable portal branch and IVC [31].

14.5 Management of on-Table Complications

If there is any contrast extravasation noted, balloon tamponade or placement of covered stent is the possible solution. If hepatic arterial injury is suspected, angiogram and appropriate embolisation are carried out.

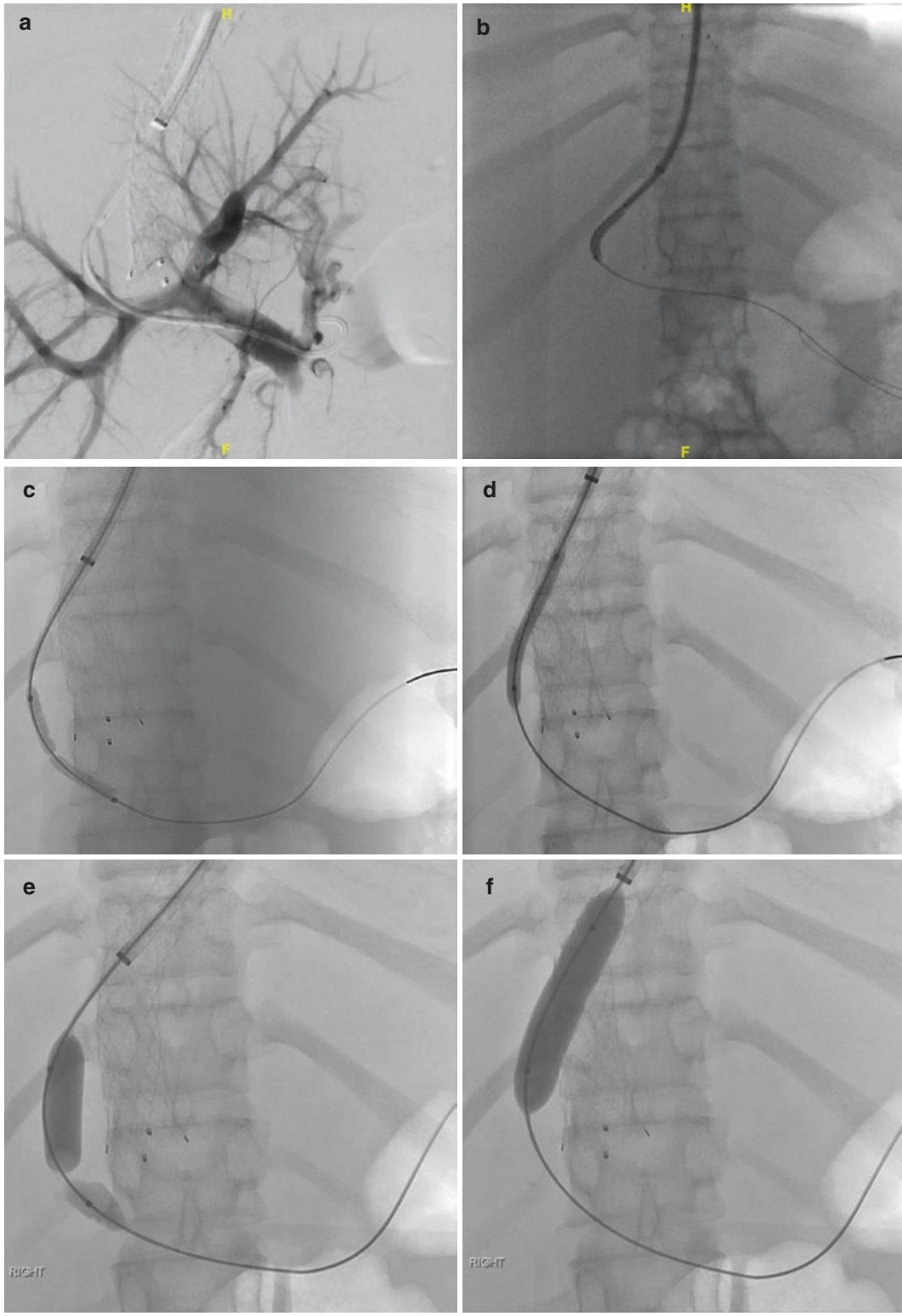

Fig. 14.3 TIPS through strut of the IVC stent: (**a**) Portogram after puncture of the portal vein (**b**, **c**, **d**, **e**, and **f**) Serial balloon plasty of the parenchymal tract with 4mm and 10x40mm balloon. (**g**) Final portogram after stent graft placement

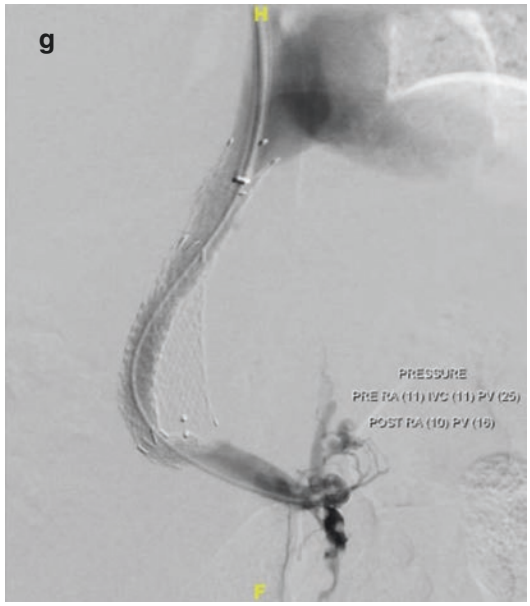

Fig. 14.3 (continued)

14.6 Management of Immediate Post-Procedure Complications

In-stent thrombosis: The thrombus may be removed endovascularly with a combination of mechanical thrombectomy and pharmacological thrombolysis.

Hepatic encephalopathy should be managed medically to the best possible extent. A shunt reduction or occlusion may be needed if there is severe hepatic encephalopathy.

14.7 Discussion

14.7.1 Outcome of the Procedure

Thresholds defined for technical success is 95% in SIR quality improvement guidelines [7] Technical success depends on many factors such as vascular anatomy and size of liver, PV size, severity of ascites, patient's body habitus, operator's experience and case load in a center. Technical success rate is high irrespective of the technique of portal vein access and range from 96% to 98.5% in various studies [32–34]. TIPS was unsuccessful in 4/107(3.7%) patients due to portal vein occlusion [32]. In an RCT technical failure rate was 1.5% in TIPS with covered stents [35]. The authors have only 1 technical failure in their 168 cases of TIPS creation using their technique described previously (publication in process).

Expanded PTFE covered stents are ideal for the creation of TIPS because uncovered or bare metal stents are associated with increased incidence of endothelial hyperplasia and early shunt dysfunction. Standard covered stent grafts meant for TIPS has a distal, fixed 2 cm uncovered portion placed in the portal vein and a covered portion of variable length for parenchymal tract, hepatic vein, and IVC. They are available in various diameters ranging from 6 mm to 12 mm depending on the need of a particular case. In a meta-analysis of 4 randomized controlled trials, TIPS with covered stents were associated with significantly higher patency of the shunt and survival compared to uncovered stent groups, and post-TIPS encephalopathy was also lower in the covered stent groups [36]. Lower incidence of encephalopathy was due to improved liver function and lower incidence of shunt dysfunction and reintervention.

14.7.2 Shunt Patency

Cumulative primary patency and secondary patency rates at 1, 2, and 5 years were 50%, 34% and 13% and 85%, 64% and 55%, respectively, in a retrospective study [36]. In a large retrospective study of 495 TIPS with Fluency stents primary patency rates at 1 and 3 years were 93%, and 76%, respectively [33]. Primary patency of the TIPS was 76% with covered stent and 36% with uncovered stents in an RCT [32]. Types of covered stent also affect shunt dysfunction rate, it was 40% in Viatorr stent and 46% with Fluency stent in an RCT comparing TIPS with covered versus BMS [35]. There was a significant difference between covered and uncovered group in terms of shunt dysfunction and clinical recurrence [35].

14.7.3 Survival

Although advanced liver disease (Child class C) is not a contraindication, however, survival after TIPS is poor in patients with advanced liver disease. Cumulative survival after TIPS was 68% at 1 year and 41% at 5 years and it was significantly higher for patients with mild liver function derangement (Child Pugh A and B) and variceal bleeding as indication compared to patients with severe liver function derangement (Child Pugh C) and ascites or hydrothorax as indication [37]. In another large retrospective study of TIPS with covered stent cumulative survival rates at 1 and 3 years were 93.4% and 77.2% respectively and it was significantly lower 25% in Child class C compared to Child class B (68%) and Child class A (89%) [34]. Survival was significantly associated with the elderly age group (>65 year), higher Child score (Child class C), and higher blood urea nitrogen level [34].

Survival rate at 1, 2, and 5 years survival rate were 98%, 92%, and 72% in TIPS with Fluency covered stent [33]. In another RCT, survival in covered stent TIPS at 1 year and 2 years was 84% and 70% respectively, and there was no significant difference in survival between covered and uncovered TIPS [35].

14.7.4 Complications

Major and minor complications which can develop during the procedure include hemorrhage due to transgression of liver capsule, inadvertent injury to artery or PV, injury to gall bladder, bile duct, right kidney, colon and rarely right atrium, shunt malposition and stent migration. Complications related to inadvertent injuries during PV access have come down due to use of real-time USG. Complications which can develop after the successful shunt creation are liver failure, hepatic encephalopathy, hemolytic anemia, contrast-induced nephropathy, hepatic infarct, fever, pulmonary oedema, heart failure and shunt migration and shunt stenosis and shunt thrombosis. Threshold set by SIR quality improvement guidelines for major and minor complications are 5% and 8%, respectively. The complication rate was 13.5% and 1mortality reported in a large retrospective study of 495 patients who underwent TIPS with covered stent [34]. Major complication was 4.85% and there was one mortality directly related to procedure at the time of shunt creation [37]. Early mortality was 3.5% (cardiac failure and hepatic failure) in an RCT in TIPS with covered stent and 6.3% in uncovered stent groups [35]. Mortality following TIPS is mostly related to the progressive downhill course of the liver disease.

In patients with high risk of encephalopathy, shunts can be created with an 8 mm stent or parenchymal tract that can be dilated with 8 mm or smaller balloon to make shunt narrower than the usual 10mm.

Rarely migration of coils and pulmonary embolism due to histoacryl migration into the pulmonary artery can occur when used for parenchymal tract embolization in traditional technique of portal vein access [34]. Risk of post-TIPS encephalopathy was associated with increased age and Child Pugh score before TIPS [32, 34]. Incidence of hepatic encephalopathy after TIPS with covered stent was 31% and 28% in bare metal stent in an RCT [33]. Incidence of at least one episode of HE during follow-up was 40% in a large retrospective study and refractory HE was 3.6%. Incidence of HE at 1 year and 2 years was 36% and 45% in TIPS with covered stent and there was no significant difference between covered and uncovered TIPS in an RCT [35]. The use of smaller diameter stent or balloon (8 mm diameter) can reduce the incidence of encephalopathy. Most of the cases are well controlled with medical management and dietary changes. Rarely shunt reduction or closure is required when medical management fails.

In a retrospective study of 103 patients, 2 needed surgical shunt (splenorenal, mesocaval) after multiple TIPS revisions and another 2 underwent liver transplant at 12 and 20 months after TIPS [37].

14.7.5 Current Status and Future Perspective

TIPS is now preferred over surgical shunts for decompression of portal hypertension in cirrhosis due to favorable periprocedural morbidity and mortality. In a Cochrane review of 4 RCT comparing TIPS and surgical portosystemic shunt for recurrent or refractory variceal bleeding and involving 496 patients, there was an increased incidence of 5 year mortality, rebleeding, shunt occlusion and shunt revisions in TIPS compared to surgical shunt. However, due to very low certainty of evidence and random errors in their analysis (due to high risk of bias, heterogeneity, small sample sizes, and publication bias), authors had very low confidence in their review findings [38]. TIPS was associated with less transfusion requirements, operative time, ICU, and hospital stay compared to surgical shunt in orthotopic liver transplant patients with similar 2 year survival in both groups [39]. In a study comparing TIPS with surgical splenorenal shunt for variceal bleed in patients for liver transplant, transfusion requirement, ICU, and hospital stay were similar however there was 3 mortality in surgical group and none in TIPS [40]. With technical modifications especially with additional image guidance, the indications for TIPS have become more. The risk of hepatic encephalopathy following the creation of the shunt still remains a challenge. However, some of the anatomical contraindications have been sorted out over a period of time. In fact, obliterated hepatic veins in Budd–Chiari Syndrome is an indication for performing TIPS, which had been considered a contraindication in previous guidelines. Another example is acute portal venous thrombosis, which is again gaining importance as an indication rather than a contraindication.

14.8 Conclusion

TIPS is a well-established intervention for the treatment of the variceal bleeding and refractory ascites arising as a complication of portal hypertension. Other indications of TIPS such as hepatorenal syndrome, PVT, hepatopulmonary syndrome, etc. are based on retrospectives studies and case series. TIPS can still be performed in most of the contraindications after corrective measures and assessing risk versus benefits in a multidisciplinary consensus meeting. Various techniques of portal vein access have been described and use of a particular technique depends on the center and operator. Technical success rate of various techniques is more than 95% and depends on vascular anatomy, operators experience, and number of cases being done in a center. Covered stent grafts should be the choice of stent for TIPS due to higher primary patency rate and lesser shunt dysfunction and reinterventions compared to other covered stents and BMS. Complications related to inadvertent transgression of liver capsule, injury to vessels and organs are lower with the use of realtime USG guidance during PV access. One should have sufficient backup facilities to tackle potential complications. The survival rate after TIPS largely depends on the severity of the liver function.

References

1. Rösch J. Development of Transjugular intrahepatic Portosystemic shunt. JVIR. 2015;26(2):220–2.
2. Rösch J, Hanafee WN, Snow H. Transjugular portal venography and radiologic Portacaval shunt: an experimental study. Radiology. 1969;92(5):1112–4.
3. Nishimine K, Saxon RR, Kichikawa K, Mendel-Hartvig J, Timmermans HA, Shim HJ, et al. Improved transjugular intrahepatic portosystemic shunt patency with PTFE-covered stent-grafts: experimental results in swine. Radiology. 1995;196(2):341–7.
4. Saad WE, Saad NE, Davies MG, Bozorgdadeh A, Orloff MS, Patel NC, Abt PL, Lee DE, Sahler LG, Kitanosono T, Sasson T, Waldman DL. Elective transjugular intrahepatic portosystemic shunt creation for portal decompression in the immediate pretransplantation period in adult living related liver transplant recipient candidates: preliminary results. JVIR. 2006;17(6):995–1002.
5. Livingstone RS, Keshava SN. Technical note: reduction of radiation dose using ultrasound guidance during transjugular intrahepatic portosystemic shunt procedure. Indian J Radiol Imaging. 2011;21:13–4.
6. Boyer TD, Haskal ZJ. The role of Transjugular intrahepatic Portosystemic shunt (TIPS) in the Management of Portal Hypertension. Hepatology. 2010;51(1):1–16.

7. Dariushnia SR, Haskal ZJ, Midia M, Martin LG, Walker TG, Kalva SP, Clark TW, Ganguli S, Krishnamurthy V, Saiter CK, Nikolic B. Quality improvement guidelines for Transjugular intrahepatic Portosystemic shunts. J Vasc Interv Radiol. 2016;27(1):1–78.
8. Garcia-Pagan JC, Caca K, Bureau C, Laleman W, Appenrodt B, Luca A. Etal.Early use of TIPS in patients with cirrhosis and variceal bleeding. N Engl J Med. 2010;362:2370–9.
9. Cirrhotic patients with portal hypertension-related bleeding and an indication for early-TIPS: a large multicentre audit with real-life results. J Hepatol. 2018;68(1):73–81.
10. Garcia-Pagán JC, Di Pascoli M, Caca K, Laleman W. Use of early-TIPS for high-risk variceal bleeding: results of apost-RCT surveillance study. J Hepatol. 2013;58(1):45–50.
11. Halabi SA, Sawas T, Sadat B, Jandali A, Halabi HA, Halabi FA, Kapoor B, Carey WD. Early TIPS versus endoscopic therapy for secondary prophylaxis after management of acute esophageal variceal bleeding in cirrhotic patients: a meta-analysis of randomized controlled trials. J Gastroenterol Hepatol. 2016 Sep;31(9):1519–26.
12. Spencer EB, Cohen DT, Darcy MD. Safety and efficacy of transjugular intrahepatic portosystemic shunt creation for the treatment of hepatic hydrothorax. J Vasc Interv Radiol. 2002 Apr;13(4):385–90.
13. Wilputte JY, Goffette P, Zech F, Godoy-Gepert A, Geubel A. The outcome after transjugular intrahepatic portosystemic shunt (TIPS) for hepatic hydrothorax is closely related to liver dysfunction: a long-term study in 28 patients. Acta Gastroenterol Belg. 2007;70:6–10.
14. Siegerstetter V, Deibert P, Ochs A, Olschewski M, Blum HE, Rössle M. Treatment of refractory hepatic hydrothorax with transjugular intrahepatic portosystemic shunt: long-term results in 40 patients. Eur J Gastroenterol Hepatol. 2001 May;13(5):529–34.
15. Dhanasekaran R, West JK, Gonzales PC, Subramanian R, Parekh S, Spivey JR, Martin LG, Kim HS. Transjugular intrahepatic portosystemic shunt for symptomatic refractory hepatic hydrothorax in patients with cirrhosis. Am J Gastroenterol. 2010 Mar;105(3):635–41.
16. Seijo S, Plessier A, Hoekstra J, et al. Good long-term outcome of Budd-Chiari syndrome with a step-wise management. Hepatology. 2013;57(5):1962–8.
17. Rössle M, Olschewski M, Siegerstetter V, Berger E, Kurz K, Grandt D. The Budd-Chiari syndrome: outcome after treatment with the transjugular intrahepatic portosystemic shunt. Surgery. 2004;135(4):394–403.
18. Garcia-Pagán JC, Heydtmann M, Raffa S, et al. TIPS for Budd-Chiari syndrome: long-term results and prognostics factors in 124 patients. Gastroenterology. 2008;135(3):808–15.
19. Keshava SN, Kota GK, Mammen T, Jeyamani R, Moses V, Govil S, Kurian G, Chandy G. Direct intrahepatic cavo-portal shunts in Budd-Chiari syndrome: role of simultaneous fluoroscopy and trans-abdominal ultrasonography. Indian J Gastroenterol. 2006 Sep-Oct;25(5):248–50.
20. Ahmed M, Keshava SN, Moses V, Chiramel GK, Mammen S, Eapen CE, Zachariah UG. Transjugular intrahepatic Portosystemic shunt through the strut of a previously placed stent: technical feasibility and long-term follow-up results. Cardiovasc Intervent Radiol. 2018 Nov;41(11):1794–8.
21. Surendrababu NR, Keshava SN, Eapen CE, Zachariah UG. Transjugular intrahepatic portocaval shunt placed through the strut of an inferior vena cava stent in a patient with Budd-Chiari syndrome: a technical modification. Br J Radiol. 2010 Jan;83(985):e22–4.
22. Mammen S, Keshava SN, Kattiparambil S. Acute portal vein thrombosis, no longer a contraindication for Transjugular intrahepatic Porto-systemic shunt (TIPS) insertion. J Clin Exp Hepatol. 2015;5(3):259–61.
23. Systematic review and meta-analysis: portal vein recanalisation and transjugular intrahepatic portosystemic shunt for portal vein thrombosis. Aliment Pharmacol Ther. 2018:1–11.
24. Song T, Rössle M, He F, Liu F, Guo X, Qi X. Transjugular intrahepatic portosystemic shunt in hepatorenal syndrome: a systemic review and meta-analysis. Dig Liver Dis. 2018;50(4):323–30.
25. Tsauo J, Weng N, Ma H, Jiang M, Zhao H, Li X. Role of Transjugular intrahepatic Portosystemic shunts in the Management of Hepatopulmonary Syndrome: a systemic literature review. J Vasc Interv Radiol. 2015;26(9):1266–71.
26. Strunk H, Marinova M. Transjugular intrahepatic Portosystemic shunt (TIPS): pathophysiologic basics, ActualIndications and results with review of the literature. Rofo. 2018 Aug;190(8):701–11.
27. Copelan A, Kapoor B, Sands M. Transjugular intrahepatic portosystemic shunt: indications, contraindications, and patient work-up. Semin Intervent Radiol. 2014;31(3):235–42.
28. Farsad K, Kaufman JA. Novel image guidance technique for portal vein targeting during transjugular intrahepatic portosystemic shunt creation. Tech Vasc Interv Radiol. 2016;19(1):10–20.
29. Fidelman N, Kwan SW, JM LB, Gordon RL, Ring EJ, Kerlan RK Jr. Thetransjugular intrahepatic portosystemic shunt: an update. AJR Am J Roentgenol. 2012;199:746–55.
30. Farsad K, Fuss C, Kolbeck KJ, Barton RE, Lakin PC, Keller FS, Kaufman JA. Transjugular intrahepatic portosystemic shunt creation using intravascular ultrasound guidance. J Vasc Interv Radiol. 2012;23(12):1594–602.
31. Bureau C, Garcia Pagan JC, Layrargues GP, Metivier S, Bellot P, Perreault P, et al. Patency of stents covered with polytetrafluoroethylene in patients treated by transjugular intrahepatic portosystemic shunts: long-term results of a randomized multicentre study. Liver Int. 2007;27(6):742–7.
32. Wang L, Xiao Z, Yue Z, Zhao H, Fan Z, Zhao M, et al. Efficacy of covered and bare stent in TIPS for

cirrhotic portal hypertension: a single-center randomized trial. Sci Rep. 2016;6:21011.
33. Luo X, Zhao M, Wang X, Jiang M, Yu J, Li X, et al. Long-termpatencyand clinical outcome of the transjugular intrahepatic portosystemic shunt using the expanded polytetrafluoroethylene stent-graft. PLoS One. 2019;14(2):e0212658.
34. Perarnau J, Le Gouge A, Nicolas C, D'Alteroche L, Borentain P, Saliba F, et al. Covered vs. uncovered stents for transjugular intrahepatic portosystemic shunt: a randomized controlled trial. J Hepatol. 2014;60:962–8.
35. Qi X, Tian Y, Zhang W, et al. Covered versus bare stents for transjugular intrahepatic portosystemic shunt: an updated meta-analysis of randomized controlled trials. Therap Adv Gastroenterol. 2017;10:32–41.
36. Zhuang ZW, Teng GJ, Jeffery RF, Gemery JM, Janned'Othee B, Bettmann MA. Long-term results and quality of life in patients treated with transjugular intrahepatic portosystemic shunts. Am J Roentgenol. 2002;179(6):1597–603.
37. Brand M, Prodehl L, Ede CJ. Surgical portosystemic shunts versus transjugular intrahepatic portosystemic shunt for variceal haemorrhage in people with cirrhosis. Cochrane Database Syst Rev. 2018 Oct 31;10:CD001023.
38. Menegaux F, Keeffe EB, Baker E, et al. Comparison of Transjugular and surgical Portosystemic shunts on the outcome of liver transplantation. Arch Surg. 1994;129(10):1018–24.
39. AbouljoudMS A. Comparison of treatment with transjugular intrahepatic portosystemic shunt or distal splenorenal shunt in the management of variceal bleeding prior to liver transplantation. Transplantation. 1995;59(2):226–9.
40. Haskal ZJ, Duszak R Jr, Furth EE. Transjugular intrahepatic transcaval portosystemic shunt: the gun-sight approach. J Vasc Interv Radiol. 1996;7(1):139–42.

15 Interventions for Portal Hypertension: BRTO and PARTO

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Abbreviations

BRTO	Balloon-occluded retrograde transvenous obliteration
PARTO	Plug-Assisted Retrograde Transvenous Obliteration
TIPS	Transjugular intrahepatic portosystemic shunt
HE	Hepatic encephalopathy
STS	Sodium tetradecyl sulfate
PVT	Portal vein thrombosis

15.1 Introduction

The major complications of portal hypertension include variceal bleeding, hypersplenism, hepatic encephalopathy (HE), ascites, and hydrothorax [1, 2]. Management of these complications requires a combination of medical, surgical, endoscopic, and interventional radiological procedures. In 1984, Olsen and coworkers described the procedure of transrenal vein reflux ethanol sclerosis [3]. In 1996, Kanagawa and colleagues revived this technique using ethanolamine oleate and named it balloon-occluded retrograde transvenous obliteration (BRTO). This technique aims to achieve the action of the sclerosing agent on the endothelial lining of the blood vessel by inducing stagnation within varix and to cause endothelial damage and vascular thrombosis [4].

The major cause of morbidity and mortality in patients with portal hypertension is spontaneous rupture of the gastric varices and massive hemorrhage. TIPS is effective in reducing the portal pressure, but may not be effective in controlling gastric variceal hemorrhage as these varices bleed even at low portal pressures. Moreover, portosystemic shunt may cause serious complications such as HE. Endoscopic interventions with glue injection and band ligation remain the first line of treatment in the case of actively bleeding gastric varices. BRTO/PARTO is used for prophylactic prevention as well in cases of failed endoscopic interventions.

Basic endovascular interventional techniques of PARTO and BRTO for treatment of gastric varices and HE, their indications, contraindications with emphasis on current data and future perspective on these procedures are discussed below:

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15.2 Indications and Contraindications

15.2.1 Indications for BRTO/PARTO

- Active uncontrolled gastric variceal bleeding
- Recurrent gastric variceal bleed in patients who have failed endoscopic and medical treatment
- Contraindications for performance TIPS in patients with gastric varices
- Prophylaxis against rebleeding after primary endoscopic therapy
- Management of recurrent HE secondary to portosystemic shunt

15.2.2 Contraindications for BRTO/PARTO

- Severe uncorrected coagulopathy
- Splenic vein thrombosis
- Portal vein thrombosis (where the gastrorenal shunt is the only outflow)
- Gross ascites
- High risk esophageal varices
- Gastric varices without a gastro/lienorenal shunt

15.2.3 Hardware Required

- 5F angiographic catheter (MPA/C2/SIM1/Picard)
- 6–12 F Flexor Check-Flo Introducer with large valve assembly
- 4-F angled or curved glide catheter/microcatheter
- Angled glide wire and stiff guide wire
- Compliant balloon catheter (size of the balloon is kept 1–2 mm larger than the diameter of the gastro/lienorenal shunt), Amplatzer vascular plug (for PARTO)
- Sclerosing agent/Gelatin sponge, Lipiodol

15.2.4 Sclerosing Agents [5]

Sclerosants are agents that act by denaturing biologic tissue. When they are injected into a vascular channel, they cause endothelial damage and fibrosis. Sclerosants (like ethanolamine oleate and detergent sclerosants) are made into foam or froth by agitating with gas (carbon dioxide or air). This process causes an increase in the volume-to-sclerosant ratio, thereby increasing potency and safety [5, 6].

15.2.5 Ethanolamine Oleate

Ten percent ethanolamine oleate is usually mixed with an equal volume of non-ionic contrast medium, like iopamidol, resulting in a 5% ethanolamine oleate–iopamidol mixture. Adverse effects of ethanolamine oleate include renal failure due to its hemolytic nature and hence other sclerosing agents are preferred over it [7].

15.2.6 Sodium Tetradecyl Sulfate

Sodium tetradecyl sulfate (STS) is the commonly used sclerosing agent in the BRTO. Sabri et al. [8] found that a smaller volume of STS is required as compared to ethanolamine oleate while performing BRTO with a good safety profile.

15.2.7 Polidocanol (Hydroxy Polyethoxydodecane)

It is a detergent and widely used in varicose vein sclerotherapy [9]. Polidocanol has been effectively used as a sclerosant for balloon-occluded retrograde transvenous obliteration [6].

15.2.8 Foam Versus Liquid Sclerosant

The advantage of foam sclerosant is that it reduces the sclerosant-to-volume ratio, requiring less sclerosant per procedure [4]. In addition, the

foam sclerosant is thought to distribute better into the numerous varices and tortuousities of the gastric variceal system [4].

15.3 Pre-Procedural Evaluation of Patient

- Grade of encephalopathy, liver function tests, renal function tests, complete blood cell count, prothrombin time and international normalized ratio (INR)
- Arterial ammonia level
- Triple phase CECT of the abdomen is required to assess technical feasibility of BRTO in terms of afferent & efferent gastric variceal anatomy of the patient, size of the shunt, and normal variants (Fig. 15.1).

It is very important to understand the gastric variceal anatomy while planning a BRTO/PARTO procedure. The gastric varices along with gastro/lienorenal shunt have a complex anatomy mostly due to variation in the veins supplying as well as draining the gastric varices [10]. The gastric varices are supplied by either

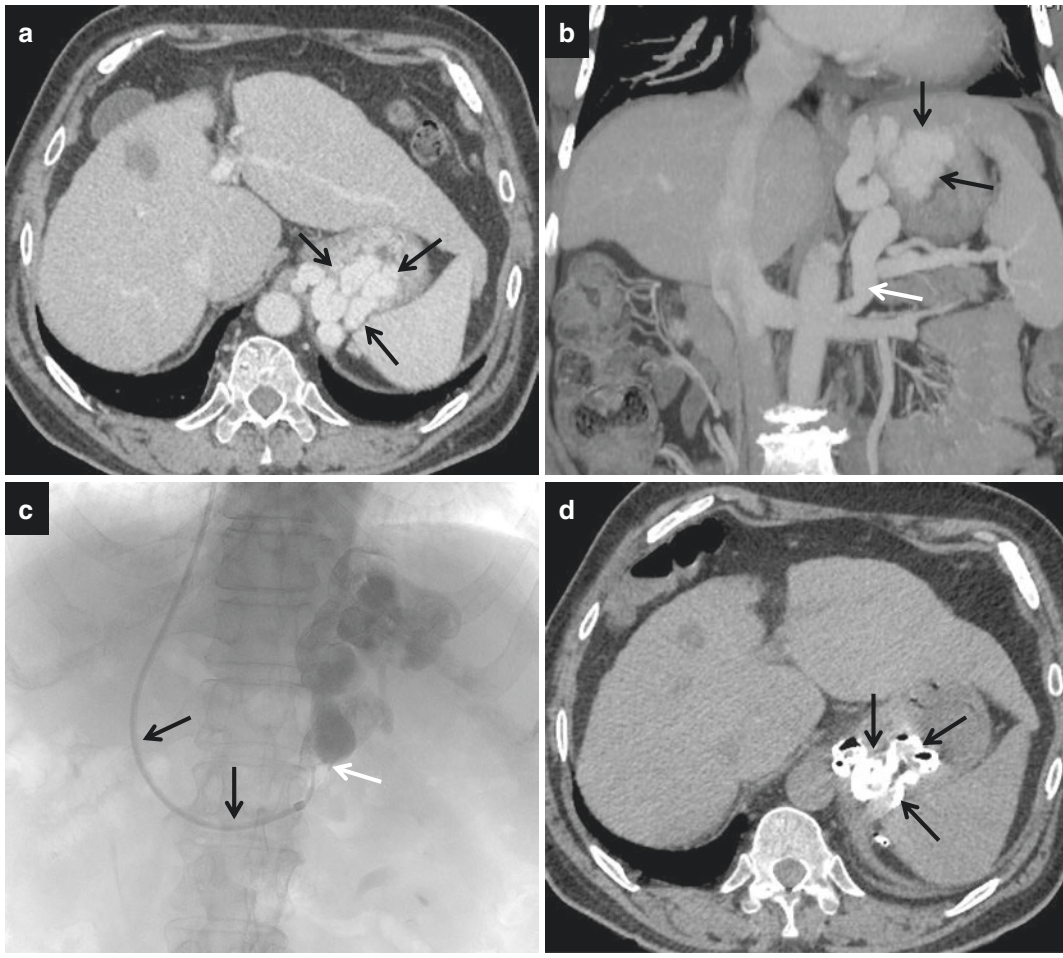

Fig. 15.1 CECT axial image (**a**) shows large gastric fundal varices protruding into the gastric lumen (black arrows), coronal reformatted image (**b**) shows large gastric varices (black arrows) with a lieno renal shunt (white arrow). Fluoroscopic image shows BRTO procedure with access taken from jugular route and vascular sheath placed within the left renal vein (black arrows) with a compliant balloon catheter inflated within the shunt (white arrow) and sclerosant mixture filling the shunt and the varices. Post-procedure CT image (**d**) showing complete obliteration of varices with formation of sclerosant cast (black arrows)

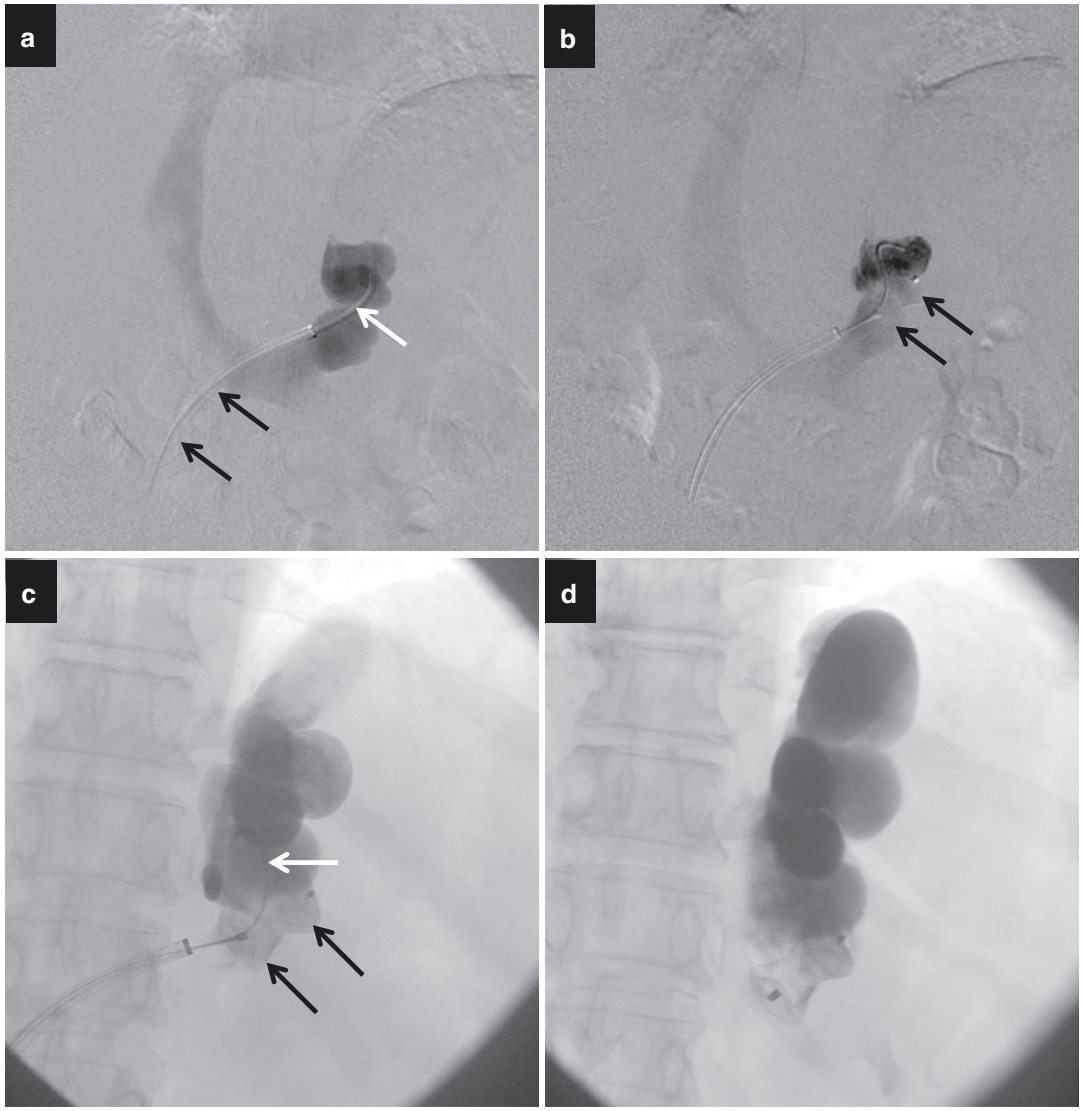

Fig. 15.2 Angiographic image (**a**) shows PARTO procedure being performed via femoral approach and vascular access sheath placed in the left renal vein (black arrows) with its tip within the lienorenal (LR) shunt and an angiographic catheter coaxially placed inside the LR shunt (white arrow). Image (**b**) shows placement of vascular plug (black arrows) within the shunt and a microcatheter coaxially placed deep within the shunt with contrast venogram being performed. Fluoroscopic image (**c**) shows deployed plug (black arrows) occluding the shunt with microcatheter (white arrow) being used to inject gel foam slurry, (**d**) shows final image with complete obliteration of the gastric varices and the LR shunt

left gastric/short gastric/posterior gastric vein or combination of any two or all three veins. The gastric varices are then drained by gastro-renal/lienorenal/gastro-lieno-renal shunt into the left renal vein and/or IVC or rarely into other systemic veins [10]. There may be variations in draining channels as well. These variations should be recognized prior to the procedure for the successful obliteration of varices (Fig. 15.2).

15.4 Technique

15.4.1 BRTO Procedure

1. BRTO is performed under local anesthesia or conscious sedation.
2. The left renal vein is accessed via femoral vein approach, alternatively internal jugular vein approach can also be used. Alternative routes are utilized for gastric varices when there is no gastrorenal shunt (alternative routes are more commonly required with duodenal and mesenteric varices compared with gastric varices).
3. A 6 to 12-French vascular sheath is placed in the left renal vein.
4. The target shunt (typically gastrorenal shunt via left renal vein) is catheterized using a selective catheter [e.g., Simmons or Cobra; (Cook, Bloomington, IN) selective catheter].
5. Compliant balloon is advanced into the shunt and inflated to occlude the shunt. (The size of the balloon is kept 1–2 mm larger than the diameter of the gastro/lienorenal shunt).
6. After occluding the shunt, contrast is injected upstream of the occlusion via the distal lumen port of occlusion balloon to evaluate variceal anatomy and identify collateral vein, if any.
7. Significant efferent collateral vessels are embolized using coils, and/or gel foam and sclerosant. It is necessary to confirm the complete occlusion of the shunt before the sclerosant agent is injected.
8. Sclerosant is injected upstream of the balloon into the gastric varices, with the occlusive balloon remaining in place for 6–12 h. During this period, the patient is kept in the angiography suite or in the recovery area beside the angiography suite.
9. Care should be taken to decide the endpoint which consists of complete coverage of the varices with sclerosant without any spill of sclerosant into the spleno-portal axis. Conebeam CT may be used to confirm complete occlusion.
10. Post-procedural follow-up imaging at 24–48 h can be done with plain CT scan of the abdomen to ensure complete obliteration of the shunt and the varices.
11. Thereafter, regular clinical and imaging follow-up is scheduled with the hepatologist and interventional radiologist.

15.4.2 PARTO Procedure

1. The procedure is performed under local anesthesia or conscious sedation after written informed consent is obtained.
2. The choice of access is femoral vein approach; alternatively, internal jugular vein approach can be used in difficult anatomy.
3. A 6 to 12-French vascular sheath is advanced and placed within the target shunt for deployment of the vascular plug.
4. A microcatheter is advanced deep within the shunt beyond the specified location planned for the placement of the vascular plug.
5. The vascular plug is inserted co-axially through the sheath and deployed to occlude the shunt. (The size of the plug is kept 2–4 mm larger than the diameter of the gastro−/lienorenal shunt and varied from 10 to 22 mm, Amplatzer vascular plug type 2 (AVP; St. Jude Medical, Inc., St. Paul, MN, USA).
6. Once the vascular plug is placed at the desired location contrast is injected upstream of the occlusion with the microcatheter (retrograde venography) to confirm adequacy of the occlusion. In case any significant efferent vein is identified then it should be embolized using embolization coils/gel foam slurry.
7. After complete occlusion of the shunt is confirmed gel foam slurry mixed with contrast is injected through the microcatheter to completely fill the shunt and varices.
8. Care should be taken to decide the endpoint which consists of complete coverage of the varices with gel foam slurry/sclerosant without any spill of sclerosant into the spleno-portal axis. Conebeam CT may be used to confirm complete occlusion.

9. Post-procedural follow-up imaging at 24–48 h can be done with plain CT scan of the abdomen to ensure complete obliteration of the shunt and the varices.
10. Thereafter, regular clinical and imaging follow-up is scheduled with the hepatologist and interventional radiologist.

15.4.3 Complications

1. Typically, transient and self-limited epigastric/back pain, fever, hematuria, nausea [11–17]
2. Worsening of esophageal varices due to increased portal pressures.
3. Temporary worsening of ascites or hydrothorax [12]
4. Altered respiratory function (presumably secondary to altered pulmonary perfusion) [18].
5. Chances of balloon rupture are minimal but such rupture can cause rapid migration of sclerosant into the right ventricle and pulmonary embolism [19].
6. Recurrent gastric variceal bleeding.
7. Gelfoam embolization to pulmonary arteries though the collateral veins.

15.5 Success Rate

The procedural success rate of BRTO in patients with portosystemic shunts and gastric varices ranges from 79% to 100% according to various studies [20–25]. In these studies, gastric variceal rebleeding rate ranges between 0% and 20% [20–28] after a successful BRTO. In a recent meta-analysis [29] including 1016 patients from 24 studies, the technical success rate was found to be 96.4%. The clinical success rate was 97.3% at a mean follow-up of 487 days, with clinical success defined as no recurrence or rebleeding from gastric varices or complete obliteration of varices on subsequent imaging. The flow velocity and flow volume in the varices have been correlated with outcomes after BRTO, with slow flow and low volume being associated with a higher success rate [30].

15.6 BRTO and Complications

The most important long-term concern after BRTO remains aggravation of non-gastric (i.e., esophageal or duodenal) varices. In four studies evaluating 160 patients who underwent BRTO with continuous post-BRTO endoscopic follow-up, the esophageal variceal aggravation rates at 1, 2, and 3 years were: 27% to 35%, 45% to 66%, and 45% to 91% respectively [11, 31–33]. In the meta-analysis by Park et al. [31], the esophageal variceal recurrence rate was 33.3%. The risk of esophageal varices aggravation has been shown to correlate significantly with the total bilirubin level and a portosystemic gradient >13 [34]. Thus, pre-BRTO prophylactic esophageal variceal eradication, portosystemic gradient measurement, laboratory analysis, and post-BRTO surveillance may be helpful to avoid subsequent esophageal variceal hemorrhage. Other complications due to raised portal pressure following BRTO include occurrence of portal hypertensive gastropathy (in 5%–13%), ascites (in 0%–44%), and hydrothorax/pleural effusion (in 0%–8%) [23, 25, 28, 31, 33]. Performance of TIPS in patients undergoing BRTO has been correlated with significantly lower ascites/hydrothorax rates and lower recurrent hemorrhage rates, although survival remains similar [35]. Furthermore, concomitant performance of partial splenic embolization also can mitigate esophageal variceal aggravation.

15.7 BRTO Versus TIPS

The retrospective studies that included intra-institutional comparison between BRTO and TIPS had a total of 133 BRTO cases and 94 TIPS cases [20, 36]. Ninoi et al. [20], compared patients undergoing only TIPS versus BRTO, reported a 1-year rebleeding rate of 20% after TIPS, while just 2% after BRTO ($P < 0.01$). Furthermore, the 1-, 3-, and 5-year survival rates after BRTO were better than those after uncovered stent TIPS 96%, 83%, and 76% versus 81%, 64%, and 40%, respectively ($P = 0.01$). However, a more recent study comparing covered TIPS

with BRTO revealed statistically similar rebleeding rates. Sabri et al. [36] reported a 1-year rebleeding rate of 11% in the TIPS group and 0% in the BRTO group (P = 0.25) with a hepatic encephalopathy rate of 15% and 0% (P = 0.12). Kim et al. [37] reported a 7% and 8% rebleeding rate throughout the study duration, respectively, but with a higher rate of hepatic encephalopathy after TIPS (22% versus 0%, P = 0.01).

15.8 BRTO and Portal Venous Thrombosis

There is a paucity of literature on BRTO with portal vein occlusion. Generally, BRTO in this setting can be associated with grave consequences, as the gastric varices may be the sole or dominant outflow for the entire spleno-mesenteric circulation; thus, occlusion of this outflow could result not only in splenic engorgement and infarction, it could also result in mesenteric venous congestion and leading to venous mesenteric ischemia [38]. One small case series of 2 patients described successful BRTO in a non-cirrhotic patient with subacute portal vein thrombosis with complete resolution of gastric varices on endoscopy 105 days post-procedure and on CT 5 months post-procedure. The second patient had chronic portal vein occlusion with cavernous transformation and splenic vein thrombosis that was due to necrotizing pancreatitis with multiple failed endoscopic treatments of her gastric varices [39]. BRTO was again successfully performed, with resolution of variceal bleeding and continued complete obliteration of varices at 6 months.

15.9 BRTO Versus PARTO

PARTO has certain advantage over BRTO. First, there is no risk of balloon rupture and subsequent pulmonary embolism, which can be fatal. The rupture of the balloon is attributed to the corrosive nature of the lipiodol used in sclerosant foam. Second, the dose limitation of sclerosants is not an obstacle for PARTO, because gel foam slurry is used instead of sclerosant mixture. Moreover, gel foam is safer embolic material than ethanolamine oleate or STS [28]. Third, PARTO does not require a long procedure time with indwelling balloon catheter and monitoring. The disadvantage of PARTO includes inability to access the shunt in case of recanalization/partial obliteration due to the presence of vascular plug.

15.10 Modifications of BRTO

Modifications of BRTO/PARTO use coils (CARTO, Coil assisted retrograde transvenous obliteration) for the occlusion of efferent flow in larger shunts followed by embolization of the varices. The advantage of CARTO is that deployment of coils does not require placement of sheath into the shunt hence making easier in cases of extreme tortuosity of shunt/varices. However, it is difficult to occlude large shunt with bunch of coils and may lead to partial occlusion. Modified techniques of BRTO include antegrade approach through portal vein [trans-TIPS or percutaneous trans-hepatic obliteration (PTO)] or a BRTO from an unconventional systemic vein. These modifications can be used in selective cases depending on factors like vascular anatomy seen on multiphasic CECT, presence or absence of ascites, INR of the patient and the location of the varices (duodenal, and other ectopic varices). It is postulated that obliteration of the portosystemic shunt by BRTO/PARTO leads to an increased portal pressure and portal hepatic blood flow with resultant improvement in hepatic function and enhanced ammonia detoxification by the liver.

15.10.1 Future Directions

There are endless innovative procedures that can be performed, incorporating the principal behind the BRTO procedure. There have been few case reports demonstrating such applications of this technique, including treatment of small-bowel varices, parastomal varices, and spontaneous mesenteric portosystemic shunts [40–44].

Management of gastric varices with modified techniques of BRTO, like BATO, CARTO, PARTO, or a combination of these is being practiced with greater frequency and is well documented in the literature [45–48]. Techniques using both endoscopic and percutaneous approaches, known as balloon-occluded endoscopic injection sclerotherapy are also being applied to prevent hemorrhage from gastric varices located in short gastric or posterior gastric territories.

15.11 Conclusion

BRTO and PARTO are endovascular procedures performed in patients with portosystemic shunts leading to gastric variceal bleeding and hepatic encephalopathy. These procedures are time tested and reliable at achieving the desired outcome with fewer associated risks and complications. PARTO is a step ahead of BRTO and lacks the risk of balloon rupture. Further modifications and variations of these procedures are being consistently employed in challenging cases with anatomic variations.

References

1. Choi YH, Yoon CJ, Park JH, Chung JW, Kwon JW, Choi GM. Balloon-occluded retrograde transvenous obliteration for gastric variceal bleeding: its feasibility compared with transjugular intrahepatic portosystemic shunt. Korean J Radiol. 2003;4(2):109–16.
2. Gluud LL, Klingenberg S, Nikolova D, Gluud C. Banding ligation versus beta-blockers as primary prophylaxis in esophageal varices: systematic review of randomized trials. Am J Gastroenterol. 2007;102(12):2842–8.
3. Kanagawa H, Mima S, Kouyama H, Gotoh K, Uchida T, Okuda K. Treatment of gastric fundal varices by balloon-occluded retrograde transvenous obliteration. J Gastroenterol Hepatol. 1996;11:51–8.
4. Saad WE. The history and evolution of balloon occluded retrograde transvenous obliteration (BRTO): from the United States to Japan and back. Semin Intervent Radiol. 2011;28:283–7.
5. Patel A, Fischman AM, Saad WE. Balloon-occluded retrograde Transvenous obliteration of gastric Varices. Am J Roentgenol. 2012;199(4):721–9.
6. Choi SY, Won JY, Kim KA, Lee Do Y, Lee KH. Foam sclerotherapy using polidocanol for bal- loon-occluded retrograde transvenous obliteration (BRTO). Eur Radiol. 2011;21:122–9.
7. Hashizume M, Kitano S, Yamaga H, Sugimachi K. Haptoglobin to protect against renal damage from ethanolamine oleate sclerosant. Lancet. 1988;2:340–1.
8. Sabri SS, Swee W, Turba UC, et al. Bleeding gastric varices obliteration with balloon-occluded retrograde transvenous obliteration using sodium tetradecyl sulfate foam. J Vasc Interv Radiol. 2011;22:309–16.
9. Ouvry P, Allaert FA, Desnos P, Hamel-Desnos C. Efficacy of polidocanol foam versus liquid in sclero- therapy of the great saphenous vein: a multicentre randomised controlled trial with a 2-year follow-up. Eur J Vasc Endovasc Surg. 2008;36:366–70.
10. Kiyosue H, Mori H, Matsumoto S, Yamada Y, Hori Y, Okino Y. Transcatheter obliteration of gastric varices. Part 1. Anatomic classification. Radio Graphics. 2003;23:911–20.
11. Arai H, Abe T, Shimoda R, Takagi H, Yamada T, Mori M. Emergency balloon-occluded retrograde transvenous obliteration for gastric varices. J Gastroenterol. 2005;40:964–71.
12. Cho SK, Shin SW, Lee IH, et al. Balloon-occluded retrograde transvenous obliteration of gastric varices: outcomes and complications in 49 patients. AJR. 2007;189:1523. [web]W365–W372
13. Fukuda T, Hirota S, Sugimura K. Long-term results of balloon-occluded retrograde transvenous obliteration for the treatment of gastric varices and hepatic encephalopathy. J Vasc Interv Radiol. 2001;12:327–36.
14. Hiraga N, Aikata H, Takaki S, et al. The long-term outcome of patients with bleeding gastric varices after balloon-occluded retrograde transvenous obliteration. J Gastroenterol. 2007;42:663–72.
15. Kitamoto M, Imamura M, Kamada K, et al. Balloon-occluded retrograde transvenous obliter- ation of gastric fundal varices with hemorrhage. AJR. 2002;178:1167–74.
16. Sonomura T, Sato M, Kishi K, et al. Balloon- occluded retrograde transvenous obliteration for gastric varices: a feasibility study. Cardiovasc Intervent Radiol. 1998;21:27–30.
17. Takuma Y, Nouso K, Makino Y, Saito S, Shiratori Y. Prophylactic balloon-occluded retrograde trans- venous obliteration for gastric varices in compen- sated cirrhosis. Clin Gastroenterol Hepatol. 2005;3:1245–52.
18. Arai H, Abe T, Takayama H, et al. Respiratory effects of balloon occluded retrograde transvenous obliteration of gastric varices: a prospective controlled study. J Gastroenterol Hepatol. 2011;26:1389–94.
19. Park SJ, Chung JW, Kim HC, Jae HJ, Park JH. The prevalence, risk factors, and clinical outcome of balloon rupture in balloon-occluded retrograde transvenous obliteration of gastric varices. J Vasc Interv Radiol. 2010;21:503–7.

20. Ninoi T, Nakamura K, Kaminou T, et al. TIPS versus transcatheter sclerotherapy for gastric varices. AJR Am J Roentgenol. 2004;183:369–76.
21. Fukuda T, Hirota S, Sugimura K. Long-term results of balloon-occluded retrograde transvenous obliteration for the treatment of gastric varices and hepatic encephalopathy. J Vasc Interv Radiol. 2001;12:327–36.
22. Hirota S, Matsumoto S, Tomita M, Sako M, Kono M. Retrograde transvenous obliteration of gastric varices. Radiology. 1999;211:349–56.
23. Cho SK, Shin SW, Lee IH, et al. Balloon-occluded retrograde transvenous obliteration of gastric varices: outcomes and complications in 49 patients. AJR Am J Roentgenol. 2007;189:W365–72.
24. Mukund A, Rajesh S, Arora A, Patidar Y, Jain D, Sarin SK. Efficacy of balloon-occluded retrograde transvenous obliteration of large spontaneous lienorenal shunt in patients with severe recurrent hepatic encephalopathy with foam sclerotherapy: initial experience. J Vasc Interv Radiol. 2012 Sep;23(9):1200–6. https://doi.org/10.1016/j.jvir.2012.05.046.
25. Mukund A, Deogaonkar G, Rajesh S, Shasthry SM, Sarin SK. Safety and efficacy of sodium Tetradecyl sulfate and Lipiodol foam in balloon-occluded retrograde Transvenous obliteration (BRTO) for large Porto-systemic shunts. Cardiovasc Intervent Radiol. 2017 Jul;40(7):1010–6. https://doi.org/10.1007/s00270-017-1593-5.
26. Park KS, Kim YH, Choi JS, et al. Therapeutic efficacy of balloon-occluded retrograde transvenous obliteration in patients with gastric variceal bleeding. Korean J Gastroenterol. 2006;47:370–8.
27. Kumamoto M, Toyonaga A, Inoue H, et al. Long-term results of balloon-occluded retrograde transvenous obliteration for gastric fundal varices: hepatic deterioration links to portosystemic shunt syndrome. J Gastroenterol Hepatol. 2010;25:1129–35.
28. Matsumoto A, Hamamoto N, Nomura T, et al. Balloon-occluded retrograde transvenous obliteration of high risk gastric fundal varices. Am J Gastroenterol. 1999;94:643–9.
29. Park JK, Saab S, Kee ST, et al. Balloon-occluded retrograde Transvenous obliteration (BRTO) for treatment of gastric Varices: review and meta-analysis. Dig Dis Sci. 2015;60:1543–53.
30. Okugawa H, Maruyama H, Kobayashi S, Yoshizumi H, Matsutani S, Yokosuka O. Therapeutic effect of balloon-occluded retrograde transvenous obliteration for gastric varices in relation to haemodynamics in the short gastric vein. Br J Radiol. 2009;82:930–5.
31. Chikamori F, Kuniyoshi N, Shibuya S, Takase Y. Eight years of experience with transjugular retrograde obliteration for gastric varices with gastrorenal shunts. Surgery. 2001;129:414–20.
32. Ninoi T, Nishida N, Kaminou T, Sakai Y, Kitayama T, Hamuro M, et al. Balloon-occluded retrograde transvenous obliteration of gastric varices with gastrorenal shunt: long-term follow- up in 78 patients. AJR Am J Roentgenol. 2005;184:1340–6.
33. Chikamori F, Kuniyoshi N, Kawashima T, Takase Y. Gastric varices with gastrorenal shunt: combined therapy using transjugular retrograde obliteration and partial splenic embolization. AJR Am J Roentgenol. 2008;191:555–9.
34. Jogo A, Nishida N, Yamamoto A, et al. Factors associated with aggravation of esophageal varices after BRTO for gastric varices. Cardiovasc Intervent Radiol. 2014;37:1243–50.
35. Saad WE, Wagner CC, Lippert A, et al. Protective value of TIPS against the development of hydrothorax/ascites and upper gastrointestinal bleeding after balloon-occluded retrograde transvenous obliteration (BRTO). Am J Gastroenterol. 2013;108:1612–9.
36. Sabri SS, Abi-Jaoudeh N, Swee W, et al. Short-term rebleeding rates for isolated gastric varices managed by transjugular intrahepatic portosystemic shunt versus balloon-occluded retrograde transvenous obliteration. J Vasc Interv Radiol. 2014;25:355–61.
37. Kim SK, Lee KA, Sauk S, Korenblat K. Comparison of Transjugular intrahepatic Portosystemic shunt with covered stent and balloon-occluded retrograde Transvenous obliteration in managing isolated gastric Varices. Korean J Radiol. 2017;18:345–54.
38. Saad WE, Kitanosono T, Koizumi J, Hirota S. The conventional balloon-occluded retrograde transvenous obliteration procedure: indications, contraindications, and technical applications. Tech Vasc Interv Radiol. 2013;16:101–51.
39. Borghei P, Kim SK, Zuckerman DA. Balloon occlusion retrograde transvenous obliteration of gastric varices in two non-cirrhotic patients with portal vein thrombosis. Korean J Radiol. 2014;15:108–13.
40. Zamora CA, Sugimoto K, Tsurusaki M, et al. Endovascular obliteration of bleeding duodenal varices in patients with liver cirrhosis. Eur Radiol. 2006;16:73–9.
41. Hashimoto N, Akahoshi T, Yoshida D, et al. The efficacy of balloon-occluded retrograde transvenous obliteration on small intestinal variceal bleeding. Surgery. 2010;148:145–50.
42. Hayashi S, Baba Y, Senokuchi T, Ueno K, Nakajo M. Successful portal-systemic shunt occlusion of a direct shunt between the inferior mesenteric vein and inferior vena cava with balloon-occluded retrograde transvenous obliteration following recanalization after placing a covered stent in the portal and superior mesenteric veins. Jpn J Radiol. 2009;27:180–4.
43. Minami S, Okada K, Matsuo M, Kamohara Y, Sakamoto I, Kanematsu T. Treatment of bleeding stomal varices by balloon-occluded retrograde transvenous obliteration. J Gastroenterol. 2007;42:91–5.
44. Minamiguchi H, Kawai N, Sato M, et al. Balloon occlusion retrograde transvenous obliteration for inferior mesenteric vein-systemic shunt. J Vasc Interv Radiol. 2011;22:1039–44.
45. Araki T, Hori M, Motosugi U, et al. Can balloonoccluded retrograde transvenous obliteration be performed for gastric varices without gastrorenal shunts? J Vasc Interv Radiol. 2010;21:663–70.

46. Saad WE, Sze DH. Variations of balloon-occluded transvenous obliteration (BRTO): balloon-occluded antegrade transvenous obliteration (BATO) and alternative/adjunctive routes for BRTO. Semin Intervent Radiol. 2011;28:314–24.
47. Kageyama K, Nishida N, Matsui H, Yamamoto A, Nakamura K, Miki Y. Successful balloon-occluded retrograde transvenous obliteration for gastric varix mainly draining into the pericardiophrenic vein. Cardiovasc Intervent Radiol. 2012;35:180–3.
48. Minamiguchi H, Kawai N, Sato M, et al. Balloonoccluded retrograde transvenous obliteration for gastric varices via the intercostal vein. World J Radiol. 2012;28:121–5.

16 Interventions for Portal Hypertension: Splenic Artery Embolization

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Splenic arterial interventions are alternative to surgery for the management of conditions like portal hypertension, hypersplenism, splenic arterial aneurysm, splenic trauma, and splenic neoplasm. Partial splenic embolization (PSE) is accepted for the treatment of leukocytopenia and thrombocytopenia produced by hypersplenism and is considered a decent option to splenectomy [1]. Presently PSE is used in some selected patient to treat major sequelae of portal hypertension, where other form of therapy is not useful or feasible; this includes variceal hemorrhage, hypersplenism, hepatogenic ascites, and hepatic encephalopathy. Interventional radiologist should be familiar with the indication, contraindication, and different types of splenic artery embolization techniques used. Splenic embolization is also used in combination with supplementary treatments for the moderation of portal hypertension and accompanying sequelae of portal hypertension.

Indications

- Variceal hemorrhage (prevention and treatment)
- Hypersplenism
- Hepatogenic ascites
- Hepatic encephalopathy

Contraindications

- Infection (Local/systemic)

16.1 Variceal Hemorrhage

Portal hypertension in cirrhotic patients leads to the formation of varices. This along with a low platelet count increases the risk for catastrophic hemorrhage. Thrombocytopenia in these patients results due to stasis of platelet in the enlarged spleen [2]. Endoscopic obliteration of gastroesophageal varices and the creation of a transjugular intrahepatic portosystemic shunt (TIPS) are the two most widely used method to manage variceal hemorrhage. Further, liver transplantation remains the ultimate treatment for advanced liver disease with portal hypertension. However, some patients are neither suitable for TIPS nor fit for liver transplantation.

Splenic embolization was initially used to reduce the occurrence of variceal bleeding in patients with portal hypertension. First this was performed in 1973 using an autologous blood clot to treat recurrent gastrointestinal hemorrhage from esophageal varices [1]. Embolization may be some times combined with other therapeutic interventions, such as endoscopic ligation [3, 4] or balloon-occluded retrograde transvenous obliteration (BRTO) [5]. PSE along with endoscopic variceal ligation is

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mainly useful in subset of ill patient, where thrombocytopenia is main cause of bleeding from varices. PSE causes improvement in platelet count, this prevents esophageal variceal hemorrhage and may help in recovery of patients' clinical status [6]. Pälsson et al. found significant increase in hemoglobin, leukocyte, and thrombocyte cell count with improvement in mean survival (50.5 months) in 26 patients treated with partial splenic embolization for esophageal varices or thrombocytopenia [6]. Similarly, in a study by Ohmoto et al. esophageal varices bleeding rate decreased from 4.3% in the pretreatment group to 1.1% after PSE in 84 cirrhotic patients with large esophageal varices and thrombocytopenia. In this study, 42 patients received endoscopic variceal ligation (EVL) and 42 received combination of EVL and PSE. They also showed improved overall survival from 31% to 50% [7]. Review of five studies by Koconis et al., which included 50 patients of PSAE, showed decrease in the yearly occurrence of variceal hemorrhage by 80% [8].

16.2 Liver Function

PSE has been used as a tool to improve liver functions in cirrhotic patients [9]. Improvements in 12 month cholinesterase, cholesterol, total protein, prothrombin time, and albumin level have been validated in few studies [10, 11]. PSE leads to decrease in portal pressure and thus reduces injury to the liver parenchyma.

16.3 Blood Parameters

Splenic embolization is also used to increase white blood cells and platelets in cirrhotic patients and specially indicated in symptomatic patient like patient having repeated skin rashes or frequent skin infections. Decreased splenic sequestration and increase in thrombopoietin levels lead to increase in platelet concentration [6, 12].

16.4 Hepatogenic Refractory Ascites/Hepatic Encephalopathy

Post-PSE decrease in effective splenic volume significantly reduces the venous drainage and thus, a decline in portal venous flow and hence the pressure. The reduction in portal pressure suggests a potential role for PSE in the spectrum of therapies used to treat advanced portal hypertension, especially in patients with borderline liver dysfunction and encephalopathy. PSE may be useful in patient with refractory ascites, where TIPS is not desirable because of some comorbid condition or advanced liver dysfunctions.

16.5 Technique

16.5.1 Type of Intervention—Partial Splenic Embolization

Partial splenic embolization—Two methods are usually used for PSE: Selective PSE and Nonselective PSE. In selective partial embolization, as name suggests, a few intraparenchymal splenic artery branches are super selectively catheterized, and embolized to achieve complete stasis of blood flow in 50% of splenic parenchyma (Fig. 16.1); while other branches of remaining splenic parenchyma show persistent blood flow. Initial baseline angiograms are useful to calculate the volume of the splenic tissue to be embolized. In nonselective partial embolization, the catheter tip is placed in the main splenic artery but beyond the origin of major pancreatic branches and embolic particles is injected until the parenchymal blush is reduced by around 50%.

Fever, local or systemic infections are contraindications for the procedure, as they are associated with increased risk of abscess formation in the infarcted tissue or aggravation of systemic infection.

Common femoral artery access is gained by Seldinger technique and 5F sheath is placed. A C2 or SIM1 catheter is usually used to cannulate the celiac axis. Main splenic artery is cannu-

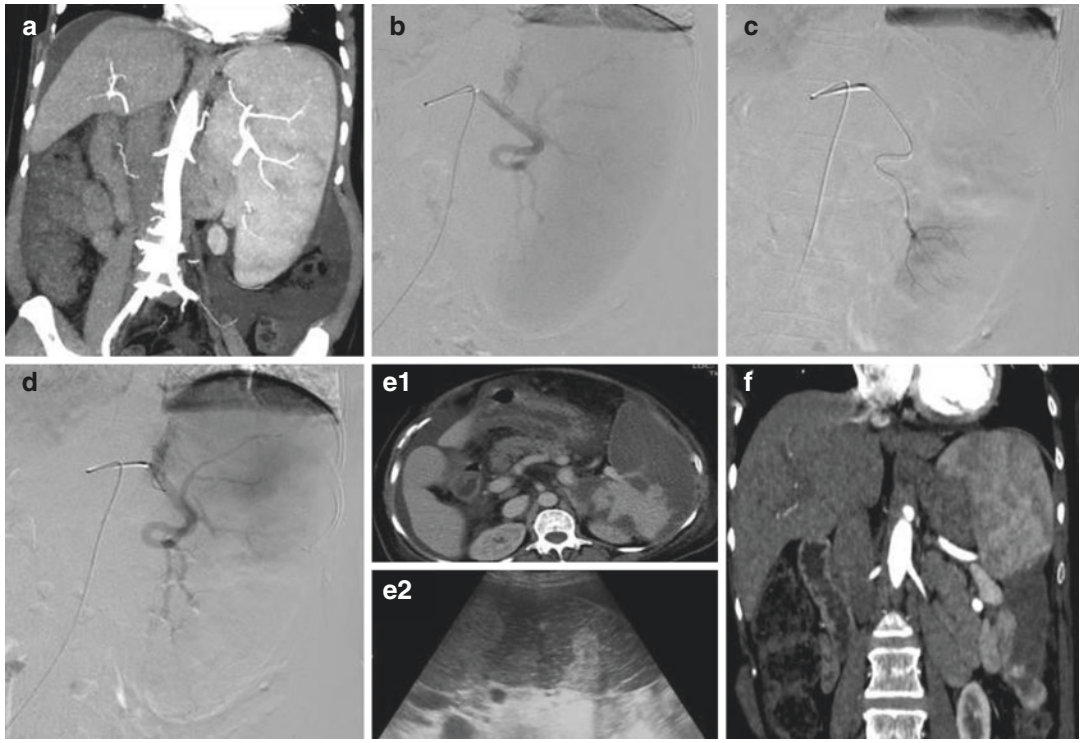

Fig. 16.1 Selective partial splenic embolization—CT abdomen arterial phase coronal image (**a**), showing cirrhotic liver with gross splenomegaly and moderate ascites. Initial baseline splenic angiographic images (**b**) delineated the anatomy of splenic artery and parenchymal blush. Super selective angiogram image (**c**) using microcatheter and final check splenic angiographic images obtained after embolization (**d**) showing complete occlusion of the lower-mid segmental splenic arterial branches (~50%). Axial CT scan image (**e1**) and USG image (**e2**) shows an infarcted area in the splenic parenchyma. Follow-up coronal CT scan image (**f**) obtained 1 year later shows atrophic mid-lower pole of the spleen and complete resolution of ascites

lated and angiogram is performed to evaluate the splenic arterial branches as well as the origin of pancreatic branches. A micro catheter is used for super selective cannulation of splenic artery branches for embolization (Fig. 16.1). Embolization of the peripheral branches or middle and lower pole branches of spleen (Fig. 16.1) reduce complications such as pneumonia, left upper quadrant abdominal pain, and pleural reaction/effusion. It is also beneficial while evaluating the embolized volume after the procedure [13].

Gelatin sponge pledgets/slurry, polyvinyl alcohol particles, and coils are the embolic agents of choice for PSE [14]. PVA particles (300 to 700-μm size) suspended in contrast medium mixed with antibiotic is most commonly used. Similarly, glue (N-butyl cyanoacrylate, NBCA) with lipiodol in concentration ranging from 1:5 to 1:7 may be used to embolize the required arteries. However, special care should be taken while using glue as an embolizing agent (optimal glue concentration, avoiding ionic solutions, and flushing of the catheter with dextrose solution) to prevent nontarget embolization and polymerization of glue over the catheter tip.

The volume of splenic infarction is the determinant for therapeutic effect versus the complication of PSE when used to treat complications of portal hypertension. Ideally, 30% to 60% of splenic volume embolization is adequate however, the volume to be embolize depends upon the clinical condition of the patient. However, opinion regarding the ideal volume to be embolized is still controversial (Fig. 16.1). Small volume reduction does not improve platelet count

whereas, large volume necrosis carries high risks of complications and/or abscess formation [8]. Various studies recommend that the first embolization volume should be less than 70% of the total spleen mass, to decrease the probabilities of complications [8, 15, 16].

One study by Harned et al. [17] found that embolization leading to infraction of 30%–40% of the splenic parenchyma significantly lowers the morbidity, although there is a lesser degree of improvement in thrombocytopenia. Conservative cautious approach is advisable at initial embolization, especially in advance liver disease, and a second session of embolization, if required, may be performed subsequently.

16.6 Post-Procedure Care

Antibiotic should be started prior to the procedure and continued in perioperative period to prevent development of infection in the infracted splenic parenchyma. Routine hospital stay consists of 24 to 48 h; however the patients should be followed for a week after the procedure. Some of the patients may require continuous anti-inflammatory medications according to the symptoms.

16.7 Complications

Most of the patients will have minor side effect in the form of fever, nausea, and pain as part of post-embolization syndrome. Post-embolization syndrome is common and may be as high as 30% but generally resolve without sequelae [18]. These symptoms can be treated symptomatically with narcotics and antiemetics. Some patient may have anorexia, vomiting, pleural effusion, ascites, and ileus. Koconis et al. reported that 73% had developed a serious complication in form of abscess, pleural effusion, ascites, pneumonia, pulmonary embolus, portal vein thrombosis, liver failure, and death when the embolization volume was 70% or more [8]. Symptomatic splenic abscess may require percutaneous drainage. Large splenic infarct area and advanced liver disease (Child-Pugh class C) are risk factors for development of complications after PSE [19].

There have been few, but encouraging reports using radiofrequency ablation and microwave ablation for the treatment of hypersplenism/splenomegaly [20, 21]. In future these techniques may be used for splenic parenchyma reduction for the treatment of portal hypertension.

16.8 Conclusion

Partial splenic embolization alone or in combination with other treatments is a promising and effective alternative option in the management of portal hypertension in relatively advanced liver disease. PSE may help in decreasing the formation of ascites and esophageal variceal bleeding, and increasing hematologic indices and liver function. Patient selection, intervention technique, and post-procedure care are the key to success.

References

1. Maddison FE. Embolic therapy of hypersplenism. Investig Radiol. 1973;8:280–1.
2. Kutti J, Weinfeld A, Westin J. The relationship between splenic platelet pool and spleen size. Scand J Haematol. 1972;9:351–4.
3. Xu RY, Liu B, Lin N. Therapeutic effects of endoscopic variceal ligation combined with partial splenic embolization for portal hypertension. World J Gastroenterol. 2004;10:1072–4.
4. Taniai N, Onda M, Tajiri T, Toba M, Yoshida H. Endoscopic variceal ligation (EVL) combined with partial splenic embolization (PSE). Hepato-Gastroenterology. 1999;46:2849–53.
5. Chikamori F, Kuniyoshi N, Kawashima T, Shibuya S, Takase Y. Combination treatment of partial splenic embolization, endoscopic embolization and transjugular retrograde obliteration for complicated gastroesophageal varices. Hepato-Gastroenterology. 2004;51:1506–9.
6. Palsson B, Hallen M, Forsberg AM, Alwmark A. Partial splenic embolization: long-term outcome. Langenbeck's Arch Surg. 2003;387:421–6.
7. Ohmoto K, Yoshioka N, Tomiyama Y, Shibata N, Takesue M, Yoshida K, Kuboki M, Yamamoto S. Improved prognosis of cirrhosis patients with esophageal varices and thrombocytopenia treated by endoscopic variceal ligation plus partial splenic embolization. Dig Dis Sci. 2006;51:352–8.

8. Koconis KG, Singh H, Soares G. Partial splenic embolization in the treatment of patients with portal hypertension: a review of the English language literature. J Vasc Interv Radiol. 2007;18:463–81.
9. Hirai K, Kawazoe Y, Yamashita K, et al. Transcatheter partial splenic arterial embolization in patients with hypersplenism: a clinical evaluation as supporting therapy for hepatocellular carcinoma and liver cirrhosis. Hepato-Gastroenterology. 1986;33(3):105–8.
10. Murata K, Shiraki K, Takase K, Nakano T, Tameda Y. Long term follow-up for patients with liver cirrhosis after partial splenic embolization. Hepato-Gastroenterology. 1996;43(11):1212–7.
11. Sakata K, Hirai K, Tanikawa K. A long-term investigation of transcatheter splenic arterial embolization for hypersplenism. Hepato-Gastroenterology. 1996;43(7):309–18.
12. Rios R, Sangro B, Herrero I, Quiroga J, Prieto J. The role of thrombopoietin in the thrombocytopenia of patients with liver cirrhosis. Am J Gastroenterol. 2005;100(6):1311–6.
13. Firat A, Boyvat F, Moray G, Aytekin C, Karakayali H, Haberal M. Comparison of two different percutaneous splenic artery interventions in the treatment of hypersplenism: preliminary report. Transplant Proc. 2005;37(2):1094–8. https://doi.org/10.1016/j.transproceed.2004.12.171.
14. Madoff DC, Denys A, Wallace MJ, et al. Splenic arterial interventions: anatomy, indications, technical considerations, and potential complications. Radiographics. 2005;25(supplement 1):S191–211.
15. N'Kontchou G, Seror O, Bourcier V, et al. Partial splenic embolization in patients with cirrhosis: efficacy, tolerance and long-term outcome in 32 patients. Eur J Gastroenterol Hepatol. 2005;17(2):179–84.
16. Obatake M, Muraji T, Kanegawa K, Satoh S, Nishijima E, Tsugawa C. A new volumetric evaluation of partial splenic embolization for hypersplenism in biliary atresia. J Pediatr Surg. 2001;36(11):1615–6.
17. Harned RK 2nd, Thompson HR, Kumpe DA, Narkewicz MR, Sokol RJ. Partial splenic embolization in five children with hypersplenism: effects of reduced-volume embolization on efficacy and morbidity. Radiology. 1998;209:803–6.
18. Piffaretti G, Tozzi M, Lomazzi C, Rivolta N, Riva F, Caronno R, Castelli P. Splenic artery aneurysms: postembolization syndrome and surgical complications. Am J Surg. 2007;193(2):166–70.
19. Hayashi H, Beppu T, Okabe K, Masuda T, Okabe H, Baba H. Risk factors for complications after partial splenic embolization for liver cirrhosis. Br J Surg. 2008 Jun;95(6):744–50.
20. Feng K, Ma K, Liu Q, Wu Q, Dong J, Bie P. Randomized clinical trial of splenic radiofrequency ablation versus splenectomy for severe hypersplenism. Br J Surg. 2011 Mar;98(3):354–61. https://doi.org/10.1002/bjs.7367.
21. Assal F, El Kassas M, Esmail E, Elbadry AA, Abousaif S, Mahdy R, Elfert A. Microwave ablation in the spleen versus partial splenic artery embolisation: a new technique for hypersplenism in cirrhosis. Arab J Gastroenterol. 2017 Mar;18(1):25–9. https://doi.org/10.1016/j.ajg.2017.01.001.

17 Vascular Complications after Hepatic Transplantation: Role of Interventional Radiology in Management

Arun Gupta, Amey Narkhede, and Ajit Kumar Yadav

17.1 Introduction

Currently, hepatic transplantation has been established as the definitive treatment for end-stage liver disease and has high survival rates of 92% and 84% at 1 and 3 years respectively. It is associated with various complications related majorly to the vascular and biliary systems. The vascular complications show wide variation in the various transplant centers worldwide but are generally reported to be around 7% in deceased donor liver transplantation (DDLT), and around 13% in living donor liver transplantation (LDLT) [1–5].

Amongst the vascular complications, arterial complications are the most commonly reported to be around 5–10%. Retransplantation is required in early hepatic artery thrombosis. The venous complications are relatively less common and include portal, hepatic venous, and caval complications, each noted to be around 2% [6]. The venous complications can be treated by surgical or endovascular approach. The hepatic artery thrombosis (HAT) and portal vein thrombosis (PVT) are the dreaded complications and need to be treated aggressively [5].

The treatment options for the vascular complications include surgical treatment, percutaneous thrombolysis or angioplasty and/or stenting, retransplantation and medical management. Recently, endovascular interventions have increased as a management option for these complications due to their high success and low complication rate.

17.2 Diagnosis of Complications

Reduced liver function and deranged liver function tests are nonspecific and are noted in several of the complications. USG along with Doppler remains the first line of investigation for assessment of vascular complications and is used for routine screening in the posttransplant period.

The first posttransplant Doppler examination is often performed on the table after anastomosing the vessels to confirm the patency. The next Doppler is done within the first 24 hours of surgery. The parameters which are examined include systolic upstroke, systolic acceleration time (SAT), peak systolic velocity, and resistive index (RI). The normal hepatic arterial waveform shows a rapid systolic upstroke [7]. In the posttransplantation period, the RI is used to assess the arterial waveform. It has a range of 0.55 to 0.80 [8]. The mean hepatic arterial peak systolic velocity (PSV) although wide variation can be noted in the immediate postoperative period [9].

An increased portal venous velocity can be noted immediately after transplantation which gradually normalizes. Hepatic veins may show

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monophasic or biphasic or triphasic waveforms which usually become triphasic eventually on the follow-up studies.

Further evaluation of the vascular system may require computed tomography (CT) and CT angiography (CTA). Magnetic resonance imaging (MRI) and magnetic resonance cholangiopancreatography (MRCP) is used for evaluation of liver parenchyma and biliary systems, respectively. In case none of the above investigations are able to explain the altered liver function tests a diagnostic biopsy may be required which may be via a percutaneous route under USG guidance or via a transjugular route under fluoroscopic guidance.

17.3 We Would be Discussing this Topic Under the Following Headings

1. Arterial Complications.
   - Hepatic artery thrombosis (HAT).
   - Hepatic artery stenosis (HAS).
   - Hepatic artery pseudoaneurysm (HAP).
   - Hepatic artery rupture (HAR).
2. Venous Complications.
   - Portal venous complications.
     - Portal vein thrombosis (PVT).
     - Portal vein stenosis (PVS).
   - Hepatic vein and inferior vena cava complications (anastomotic complications leading to stenosis).
   - Splenic steal/portal hyperperfusion syndrome.
3. Arterioportal Fistula (APF).

17.3.1 Arterial Complications

The arterial complications are the most common source of morbidity and mortality after hepatic transplantation. After OLT hepatic artery remains the only arterial vascular supply to the hepatic parenchyma as well as the biliary tree since the collaterals are ligated. Thus reduced arterial flow invariably leads to biliary complications due to ischemia such as bile duct necrosis, liver abscesses, and graft dysfunction [8]. Also in case, there are hepatic artery complications the allograft may survive by portal flow but only if there are arterial collaterals [10, 11].

The arterial complications can be either early, i.e., occurring within 1 month of transplant or delayed, i.e., occurring after 1 month of transplant according to most of the authors. The early complications are very critical and should be immediately managed since these are related to high mortality and graft loss [11–13].

17.3.1.1 Hepatic Artery Thrombosis [HAT]

HAT is the most frequent and most severe vascular complication after OLT representing around 50% of all arterial complications and is the most common cause of graft loss [5, 14–16]. It has a high mortality rate ranging from 23% to 33% as well as graft loss rate of around 50% to 60% [12, 13].

The incidence rate of early HAT varies from 0% to 12% [17–20]. In 2009, Bekker et al. in a systematic review reported that 843 cases (adults and children) developed early HAT amongst the 21,822 OLT cases with an overall incidence of 4.4% [13]. In adults, the incidence of HAT was 2.9%. A lower incidence rate has been noted with late HAT. No significant difference is noted in the incidence of HAT in LDLT (3.1%) as compared to DDLT (4.6%) [13].

HAT patients present with elevated transaminases (75%), biliary complications (15%), pain, fatigue, fever, leucocytosis and sepsis (6%) and graft dysfunction or loss (4%) [5].

Early HAT usually presents with initial nonfunctioning or severe graft dysfunction as opposed to late HAT which is mostly associated with biliary complications. Thus, the acute presentation shows a more severe clinical course whereas delayed presentation shows a relatively milder course [11].

Early HAT presents with fever, leucocytosis, and elevated LFTs. The reduced blood supply to bile duct epithelium and the hepatocytes results in their injury. Biliary tract necrosis occurs which in an immunocompromised state leads to septic shock (biliary sepsis). Massive necrosis of the allograft is also noted [13, 19, 21].

Late HAT is likely due to ischaemic or immunological damages. The symptoms associated

include biliary complications such as bile duct stricture/stenosis, recurrent cholangitis biliary leakage, biliary tract necrosis, and abscess formation. However, as many as 50% of patients may be asymptomatic with only elevated LFTs. Eventually, late HAT may also lead to graft dysfunction and loss [22–24].

Surgical causes (anastomosis) account for around 20% of the HAT. The non-surgical risk factors include donor age > 60 years, extended cold ischemia time, lack of ABO compatibility, cigarette smoking, hypercoagulability state, donor positive for CMV in a CMV-negative recipient, rejection, regrafts, and transplant for primary sclerosing cholangitis [25]. TACE is also found to have a statistically significant association with radiological and histological arterial wall injury as reported by Panaro et al. in a recent study [26]. Also interestingly, in a study by Marín-Gómez et al. they reported that the intraoperative hepatic artery blood flow can predict the occurrence of HAT [27]. HA flow velocity of less than 100 ml/min intraoperatively has been found to be associated with HAT.

HAT can be suspected in case of abnormal elevation of LFTs. Doppler ultrasound is an important tool to screen for HAT. It shows a lack of color flow in HA and is the most common finding in HAT. An increased RI proximal to thrombosis may also be observed [19]. The confirmation of the diagnosis is made by computed tomography (CT) angiography.

The management options include revascularization (surgical or endovascular); retransplantation and observation.

Retransplantation offers the best survival results and is the treatment of choice. However, it is limited due to the paucity of liver donors as well as the patient's condition to undergo another major procedure [12, 19, 28]. Hence before considering re-transplantation, revascularization by endovascular means is now being increasingly considered as a lucrative option. Surgical revascularization is also an option; however, it cannot relieve extensive thrombosis involving the intrahepatic arterial system.

The percutaneous endovascular treatments include intra-arterial thrombolysis (IAT), percutaneous transluminal angioplasty (PTA), and stent placement. The intra-arterial thrombolysis offers several advantages as compared to systemic thrombolysis such as lesser thrombolytic dosage and localized high concentration, thus leading to minimal systemic side effects and fewer chances of hemorrhage [16, 29].

The IAT should be combined with balloon angioplasty with or without stent placement if the HAT is associated with anatomic defects (kinking, stenosis) [15, 29]. Currently, many centers are attempting PTA and/or stent placement in cases of HAT in combination with IAT [29]. However, PTA is associated with few complications such as thrombosis, vascular dissection, and rupture.

Acute HAT occurring in the first 5 days is managed by surgical revision at most of the centers. The time period for application of IAT is usually from 1–3 weeks to 1–3 months posttransplantation as proposed by Saad et al. in 2007 [15]. However, in cases of co-morbidities, when surgical revision is not feasible, successful IAT can be performed even in the first week posttransplantation [30]. Although in such cases the complication rate is significantly higher, IAT is the best option available for graft salvage.

Although there is ample proof of the safety and efficacy of endovascular revascularization interventions, the risk of hemorrhagic complications should be kept in mind before attempting them. These methods may help to avoid retransplantation, but only in asymptomatic patients [6, 16, 29]. There is also a lack of specific guidelines for IAT application in the literature although many different agents and regimens do exist.

It has been established that retransplantation after HAT has a better survival rate compared with revision or thrombolysis [5]. The patients who are symptomatic and show severe graft dysfunction due to early HAT require retransplantation.

Endovascular Technique

Access into the femoral artery is obtained with the insertion of a 5/6-F sheath. Diagnostic arteriography is performed using a diagnostic cobra

catheter. The occluded segment is then crossed with using a 0.014- or 0.018-inch guidewire with a microcatheter coaxially within the 5F guide catheter. After crossing the thrombosed segment continuous infusion thrombolysis is performed through a multiple-side-hole-infusion catheter. When the placement of multiple-side-hole-infusion catheter is not feasible, especially in LDLT cases, where the diameter of the artery is less, a micro-catheter having single end hole is kept in situ for thrombolysis. Thrombolytic agents such as tissue plasminogen activator (TPA) and urokinase are employed. Intra-arterial heparin is also administered concurrently through the sheath kept in situ in the femoral artery. Angiography is repeated within 24 hours followed by adjunctive techniques such as balloon maceration and/or attempted angioplasty or stent placement. Based on the patient's angiographic findings and the patient's clinical status the decision to continue thrombolysis is made. In case of a suboptimal PTA result, the stent is placed over the stenosed vessel segment. Both balloon-expandable and self-expandable stents can be employed including coronary drug-eluting stent (DES) [31].

17.3.1.2 Hepatic Artery Stenosis [HAS]

HAS has been defined as narrowing in the HA diameter leading to graft ischemia. Significant HAS is defined as reduction in HA diameter by 50% on angiography and Doppler ultrasound (DUS) findings of PSV more than 400 cm/sec, RI less than 0.5(beyond stenosis), and a parvus-tardus waveform. This is also accompanied by elevation in LFTs [32–34]. HAS is also associated with high morbidity and mortality.

HAS has a known incidence of 2% to 13% in transplants and mostly develops at the level of the anastomosis [32, 34]. It commonly occurs within 3 months after OLT [35]. Saad et al. emphasized that HAT may progress to HAS in 65% of cases after 6 months of no treatment or management.

The median time to diagnosis following OLT has been reported to be 100 days which was also reported by Denys et al. [36]. Similar to HAT, HAS may be divided into two groups: HAS occurring within 30 d after OLT (early HAS), and HAS occurring more than 30 d after OLT (late HAS). The incidence of early HAS is 40% as compared to a 60% incidence rate of late HAS.

Many of the patients are asymptomatic on presentation and are diagnosed on DUS screening. The only abnormality noted is elevated LFTs. This is the reason why post-operative screening is mandatory since the presentation of HAS is insidious. DUS has a reported sensitivity of 100%, specificity of 99.5%, a positive predictive value of 95% and a negative predictive value of 100%, and an overall accuracy of 99.5% in diagnosis of early HAS [35, 37]. The biliary complications following HAS include biliary strictures and bile leaks with an incidence of 67% in patients with post-transplant HAS. However, the rate is still less as compared with HAT [38].

The risk factors for the development of HAS include perioperative factors (technical) of vascular injury (microvascular injury from cold preservation of the liver, clamp injury, intimal dissection, faulty placement of anastomotic sutures) and donor and recipient factors (excessive length with kinking and angulation, differences in vessel caliber that require oblique anastomosis). The other factors include extrinsic compression and microvascular injury, i.e., vasa vasorum disruption, acute cellular rejection and prior transarterial chemoembolization (TACE) [32].

The management options include surgical revision, retransplant, or percutaneous endovascular interventions.

The interventional radiological procedures for HAS treatment include PTA with balloon dilatation with or without stent placement or direct stent placement across the stricture (Fig. 17.1a, b, c). Both of these methods are efficacious and show similar complication rates and decrease the re-transplantation rate [39].

Significant HAS treatment by PTA alone may lead to arterial dissection and rupture in 7% cases. Delayed complications include HAT with a 5% incidence. Primary stenting of the HA is a feasible option and as reported by few authors offers a low complication rate with an acceptable 1-year patency rate. The complication of HAR or

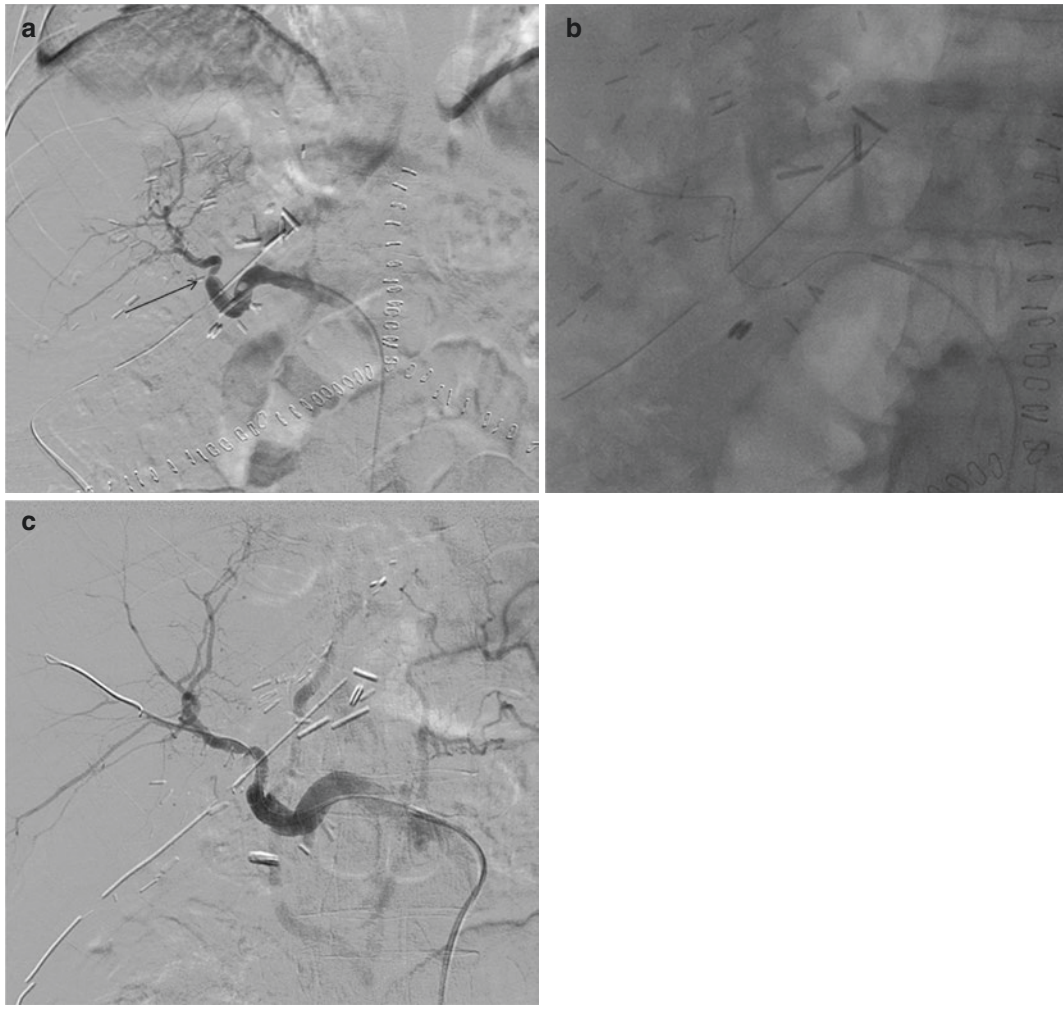

Fig. 17.1 (**a**) Stenosis noted at the site of anastomosis between the graft and recipient hepatic artery (black arrow). Angiogram is taken with the diagnostic catheter in the hepatic artery proper. (**b**) Fluoroscopic image showing balloon mounted covered stent deployed across the site of stenosis. (**c**) Post-stent placement checks angiogram taken from diagnostic catheter in the main hepatic artery showing resolution of stenosis

extravasation during PTA can be managed by use of graft-covered stents as employed and reported by Boyvat et al. This allows for safer endovascular intervention and has an acceptable benefit/risk ratio [40].

In case of failure of endovascular intervention techniques surgical revascularization should be done specially in cases of biliary complications.

Abbasoglu et al. reported 35 cases of surgical revision in their study using various techniques. The surgical revision techniques include aorto-hepatic iliac artery graft placement, autologous saphenous vein patch angioplasty and resection of the stenotic segment either with primary re-anastomosis or with interposition of a banked iliac artery or saphenous vein graft [33].

It has been noted that patients with HAS not receiving endovascular management have twice the risk of development of biliary complications and a decreased survival as compared to patients receiving this line of management [41].

The overall mortality reported in the procedures for management of HAS is 20% and is mainly attributed to the surgical revision group.

It has been suggested that HAS can be an early sign of chronic rejection and so every HAS patient should be screened for chronic rejection [33].

17.3.1.3 Hepatic Artery Pseudoaneurysm [HAP]

HAP is defined as a pooling of blood outside the arterial wall due to leak from the vessel occurring mostly due to iatrogenic HA injury. A persistent communication exists between the cavity and the artery. HAP has a low incidence rate ranging from 0.27 to 3% [42, 43].

Most of the HAP occurs in the early postoperative period around 1-month posttransplant. The median time reported varies from 13.4 to 29 days post-OLT [44].

The clinical presentation may widely vary from the patient being asymptomatic, having abdominal pain associated with fever, gastrointestinal bleeding (25%), massive hemorrhage through the abdominal drain (31%), and with hemorrhagic shock. Hemorrhagic shock was the most frequent mode of presentation in the series of Volpin et al. [44].

The predisposing factors include peritoneal infections, technical difficulties during the completion of arterial anastomosis and biliary leak [45]. It has been found that the patients in whom bacterial or fungal organisms were isolated from the peritoneal fluid or the arterial wall the rate of extrahepatic. HAP is very high.

The diagnosis of HAP can be made by DUS, contrast-enhanced CT scan, or angiography.

The management options include endovascular management or surgical repair.

The HAP can be excluded with a covered stent placed across its origin from the hepatic artery (Fig. 17.2a, b) [44]. This method is the preferred choice of treatment. There is no effect on the liver functions as well as the biliary system. The other IR methods include percutaneous injection of thrombin into the aneurysmal lesion using USG or CT guidance or coil embolization of the aneurysmal sac.

The surgical treatment includes urgent laparotomy for HA ligation. However, the immediate postoperative mortality is 60%. Also, it may lead to impaired hepatic functions and final loss

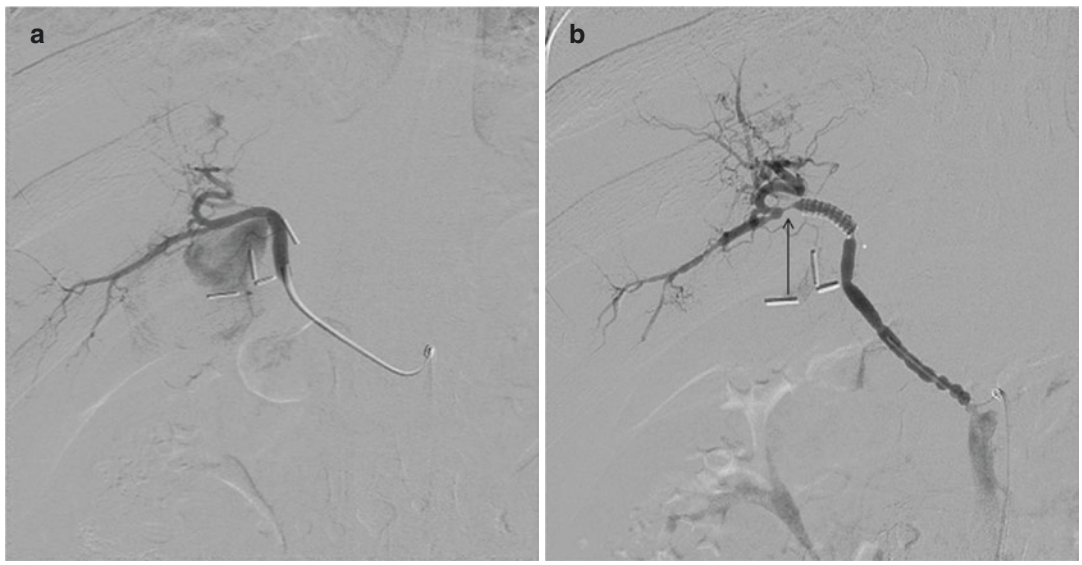

Fig. 17.2 (**a**) Angiogram is taken with diagnostic catheter in hepatic artery proper showing a large pseudoaneurysm arising from the anastomotic site. (**b**) Balloon mounted covered stent placed in hepatic artery across the site of origin of pseudoaneurysm. Angiogram shows no evidence of pseudoaneurysm. Note the reduced caliber of hepatic artery distal to stent due to arterial spasm (black arrow)

of the transplanted liver thus requiring retransplantation [44, 46].

The HAP occurs most commonly within first 5 weeks posttransplant. It has been found to be associated with a high mortality rate ranging from 69 to 100% [43, 44, 47]. The management includes opting for endovascular management followed by surgical management in case there is failure of endovascular management.

17.3.1.4 Hepatic Artery Rupture [HAR]

Hepatic artery rupture can be defined as hemorrhage occurring from the main hepatic artery or its branches and in most of the cases is a complication arising from hepatic artery pseudoaneurysm. It has very low incidence rate of 0.64% [48]. This entity carries a very high rate of graft loss and mortality and the need for retransplantation.

The etiology of HAP leading eventually to HAR is infectious especially fungal infection. The median time of development of HAR from transplantation is 29 days [48]. The patient may present with hemoperitoneum, gastrointestinal bleeding, hematoma, or hemobilia. Biliary leak may also be concurrently noted in few patients.

The diagnosis is possible by various radiological techniques, but since almost HAR is an acute life-threatening emergency, the patient is immediately taken up for endovascular interventions or surgery.

The therapeutic possibilities include IR management and surgical interventions. The interventional procedures include embolization with or without covered stent graft placement across the site of rupture.

The surgical intervention includes definitive ligation of hepatic artery, anastomotic revision, aorto-hepatic grafting, or retransplantation. The expected complications after HA ligation include ischaemic biliary complications such as ischaemic cholangitis which can be managed by percutaneous interventional techniques. It has been recommended by Boleslawski et al. in a retrospective study that HA revision should be avoided especially when mycotic pseudoaneurysms are suspected [48].

17.3.2 Venous Complications

The venous complications include complications related to the portal vein as well as the hepatic veins. They are less frequent as compared to arterial complications with an incidence rate of 3% [4, 5, 35, 49]. However if these occur in the early postoperative period, they lead to significant morbidity and mortality [49, 50]. Also these are found to have a higher incidence in pediatric liver transplants [50].

The most common site of involvement is the site of anastomosis. The portal vein complications include portal vein thrombosis and portal vein stenosis. The hepatic venous and caval complications depend upon the type of anastomosis. The end to end anastomotic complications include thrombosis and stenosis (<2%), whereas in piggyback anastomotic complications include thrombosis, stenosis, and kinking (<2%) [4, 5, 51].

All these complications may also be classified as either early (<1 month) or delayed (>1 month) complications.

17.3.2.1 Portal Vein Complications

The incidence of portal venous complications ranges from 1–3%. The portal vein thrombosis is mostly noted in the postoperative period with an incidence of <3% whereas portal vein stenosis is noted in 2–3% cases. As mentioned earlier these complications are more common with pediatric transplantation. These are also noted more commonly with split liver and LDLT transplants [52].

The endovascular interventional procedures are the first line of management for these complications except for early PVT.

Portal Vein Thrombosis (PVT)

The incidence of PVT ranges from 0.3–2.6% [53]. In a study by Duffy et al., an incidence of 2% was noted in more than 4200 patients [5]. The clinical presentation varies according to the time of development of PVT. When the PVT is early, acute graft failure occurs. When the PVT is delayed the manifestations include upper gastrointestinal bleed due to varices, ascites, etc. And

the severity depends on the extent of formation of portocaval collateral circulation [54].

The etiology of PVT is most commonly due to technical factors such as redundant vein as well as kinking with or without stenosis at the site of anastomosis. Other factors include prior surgery involving the portal circulation, pre-transplant PVT requiring thrombectomy, small diameter of portal vein (<5 mm), hypoplastic portal vein, splenectomy, large portosystemic collaterals and use of venous conduits for portal vein reconstruction.

The Doppler USG is the most convenient diagnostic tool for recognizing PVT. Hence the posttransplant screening protocol involves performing DUS either once or twice daily until postoperative day 5 or in deranged LFTs or case of clinical suspicion [55, 56]. Recently it has been found that the CEUS can help in assessing the severity of PVT based on parenchymal perfusion status.

The IR management options include percutaneous thrombolytic therapy via the transjugular intrahepatic portosystemic shunt creation, transhepatic route, or the transplenic route. The above routes can also be used for portal vein angioplasty with or without stent placement [57]. An indirect method which can be used only for thrombolytic therapy involves cannulation of superior mesenteric artery for thrombolysis [58].

PVT can also be managed with systemic anticoagulation or surgical methods including surgical revision or retransplantation.

The various management options can be employed according to the time of presentation. In case of early and complete PVT occurring within72 hrs of transplantation, the management is surgical. In a patient showing Multiorgan Dysfunction Syndrome (MODS), surgical revision of the anastomosis should be done. If the cause of thrombosis is kinking or twisting, anastomotic revision is done with systemic anticoagulation. If the anastomotic revision fails to resolve the issue, retransplantation is required.

If PVT occurs within 72 h and 30 days posttransplantation, the first line of management is non-surgical. The most preferred treatment is percutaneous thrombolysis with stent placement. Cherukuri et al. reported that the thrombolytic doses should be kept low and maintained only for a period of few hours [59, 60]. The route for stent placement is either via the transhepatic route or via trans jugular intrahepatic route (the TIPS route). The TIPS approach is preferred in patients with coagulopathy and ascites [61]. The success rate with the IR management options ranges from 68 to 100%. The mortality and morbidity rate have been found to be 0% and 11% respectively [62].

The abovementioned protocols are not stringent though. Percutaneous thrombolysis with stent placement can even be performed in the first 3 days posttransplantation in patients unable to undergo surgical revision due to co-morbid conditions.

When the presentation of PVT is late, i.e., occurring after 30 days of transplantation, the management varies according to presentation. Observation is recommended in cases of normal hepatic functions with hepato-portal collateral and portal cavernoma formation [63]. The cases presenting with gastrointestinal bleeding or ascites should be managed with percutaneous transhepatic or transjugular approaches. Complete recanalization can also be attempted with systemic low dose recombinant tissue plasminogen activator (rt-PA) continuously with 10 days along with 25,000 IU heparin per heparin [64].

Thus, with prompt diagnosis and proactive management the portal vein thrombosis can be treated effectively.

Endovascular Technique

(a) Thrombolysis through percutaneous transhepatic or transplenic portal vein cannulation:

An 18 G co-axial needle is used to take a transhepatic puncture of a peripheral branch of right portal vein. The portal vein can also be accessed by taking a trans-splenic puncture of a peripheral branch of splenic vein. An 8 Fr sheath is used to secure the access using Seldinger's technique. Then a large thin-walled thrombus aspiration introducer

catheter of 8 Fr (90 cm Cordis Corp., USA, or a 100 cm Boston Scientific Corp. USA) is used to aspirate the thrombus, as much as possible. Finally, a multiple side hole catheter of 4 Fr. (Cook Corp. USA) or a microcatheter with single end hole is introduced into the thrombus depending upon the vessel diameter and kept in situ to continuously deliver rt-PA or urokinase (0.5–1.5 MIU/d) for local thrombolysis ranging from 3 to 10 days based on the amount of thrombus. The sheath is also attached to continuous heparin infusion (30–200 mg/d). Concurrently clopidogrel (75–150 mg/d) or enteric-coated aspirin tablet (100–150 mg/d) is also administered to patients with platelet counts greater than 300×10^9/L.

Monitoring of thrombin time (TT) and activated partial thromboplastin time (APTT) is done to maintain TT at 1.5–2.5 times the normal range, and APTT at 2–2.5 times the normal range. After the treatment is completed and the catheter and sheath are withdrawn, the tract embolization is done using coils with or without glue to prevent iatrogenic bleeding (Fig. 17.3). The patient is then continued on intravenous heparin or subcutaneous low molecular weight heparin (LMWH) for additional 2 weeks and then switched over to oral warfarin sodium for not less than 1 year. During this duration, the patients are monitored with standard blood tests and the international normalized ratio (INR) which is maintained in a range of 2.0 to 3.0. Abdominal ultrasound and CT angiography are repeated every 1–3 months as required.

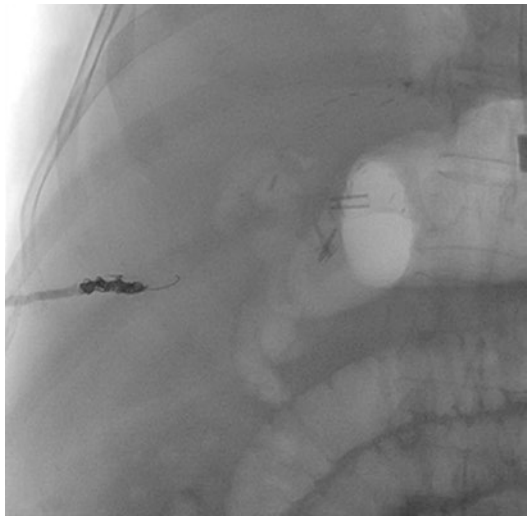

Fig. 17.3 The hepatic tract closure is done by coils deployed through the sheath followed by glue

(b) Thrombolysis through transjugular intrahepatic portosystemic shunts (TIPS)

The right IJV puncture is taken and access secured using a 6 Fr sheath. The right hepatic vein is then accessed using 0.035-inch hydrophilic guidewire and Kumpe catheter and then exchanged with a super stiff Amplatz wire. The 10 Fr long sheath (RUPS 100 system, COOK Corp, USA) is then introduced into the right hepatic vein and access secured. A branch of right portal vein is punctured using a long needle under ultrasound and fluoroscopy guidance. Contrast injection is done to confirm the puncture followed by the introduction of Terumo wire through the portal vein into the SMV. An angiographic run is taken by the introduction of a 4 Fr. catheter into the SMV to delineate the extent of thrombosis. Once the thrombosed segment is reached, the thrombolysis is performed as described above.

Portal Vein Angioplasty and/or Stenting

The thrombosed segment of portal vein is crossed employing one of the abovementioned approaches. Portography is done to understand the extent of thrombosis. The thrombus is macerated using a balloon catheter, 8 to 10 mm in diameter. This is followed by stent placement. Stents of same diameter (10 mm) or 1 to 2 mm larger diameter are used. The length of the stent varies from 4 to 10 cm depending on the extent of thrombotic segment. Post stent placement, balloon dilatation of the stent is done, if stenotic deformity of the stent is noted. This is followed by check portography to confirm the opening up of the portal system.

(c) Indirect thrombolysis via superior mesenteric artery cannulation using femoral or radial artery approaches [58].

The celiac axis and the superior mesenteric artery are catheterized via the femoral or the radial approaches after securing the access using a 5 Fr sheath. Indirect PV-SMV angiography is taken. Few holes are created at the front of Cobra catheter. Urokinase or rt-PA is then administered into the SMA through this catheter at an intensive dosage. Then, the catheter is left in situ and the thrombolysis is continued with urokinase (0.75-1.5 MIU/d) or rt-PA for a duration of 3 to 10 days. The rest of the management is same as what has been described above.

Portal Vein Stenosis (PVS)

The incidence of portal vein stenosis is unknown. It may present with complications of portal hypertension such as upper GI bleed from varices, ascites, splenomegaly, or directly with graft failure [65]. However most of the cases are asymptomatic and are usually detected during routine DUS.

The risk factors of PVS majorly includes surgical anastomotic errors. Since in pediatric population, there is discrepancy between diameter of donor and recipient portal vein this group is especially at a higher risk of PVS [49]. It has also been found that neoadjuvant chemotherapy prior to hepatic transplant such as in cholangiocarcinoma is a predisposing factor for PVS.

The early PVS is considered to be a consequence of surgical error, whereas the late PVS is assumed to be as a result of fibrosis or intimal hyperplasia [66]. If PVS is not managed promptly it may progress to PVT.

The diagnostic criteria takes into consideration the portal vein caliber, pre- and post-anastomotic velocities noted on DUS. Significant PVS has been defined as a portal stenosis ratio of >50% [67]. The portal velocity ratio is calculated as velocity at the site of stenosis: velocity in the pre-stenotic segment and a ratio of >3:1 is considered as significant PVS. A pressure gradient of >5 mm Hg across the stenosis is considered significant and is an indication to initiate treatment [66].

Surgical treatment involves anastomotic revision or retransplantation. In cases of asymptomatic patients with normal LFTs, regular follow-up and DUS screening may be enough without any active management.

The interventional radiological management is now considered as the first line of treatment for PVS [68, 69]. The approach to PVS may be via a transhepatic or transplenic or transjugular intrahepatic route although the right transhepatic route is preferred (Fig. 17.4a) [70]. It was reported by Shibata et al. that a single balloon dilatation could maintain patency in 77.7% patients (mean follow-up of 24.8 months) [68].

The PVS can be managed by balloon dilatation with or without stent placement (Fig. 17.4b, c, d, e, f). The stent can be placed either in the first setting or in cases of recurrence or inadequate response on balloon dilatation depending on the severity of stenosis (Fig. 17.5). It is recommended to start anticoagulation therapy for the prevention of portal vein or intrastent thrombosis using low molecular weight heparin, warfarin, or aspirin [71]. A follow-up every 1–3 months is advised in which the patient is screened for the status of the portal vein and intra-stent flow with DUS. The patients are monitored with standard blood tests and INR value which is maintained between 2.0 to 3.0. CT angiography can be performed in cases of abnormality found on DUS for confirmation.

Thus, it has been established now that the IR management is the method of choice for treatment of PVS with high success and a low complication and recurrence rate.

17.3.2.2 Hepatic Vein and Inferior Vena Cava Complications

The incidence rate of transplant outflow obstruction by kinking, stenosis or thrombosis of IVC or hepatic veins is less than 3% [51]. Clinical presentation varies from ascites, pleural effusion, Budd–Chiari Syndrome, lower limb edema, allograft loss, and multiorgan failure [72]. The main risk factor for early complication includes

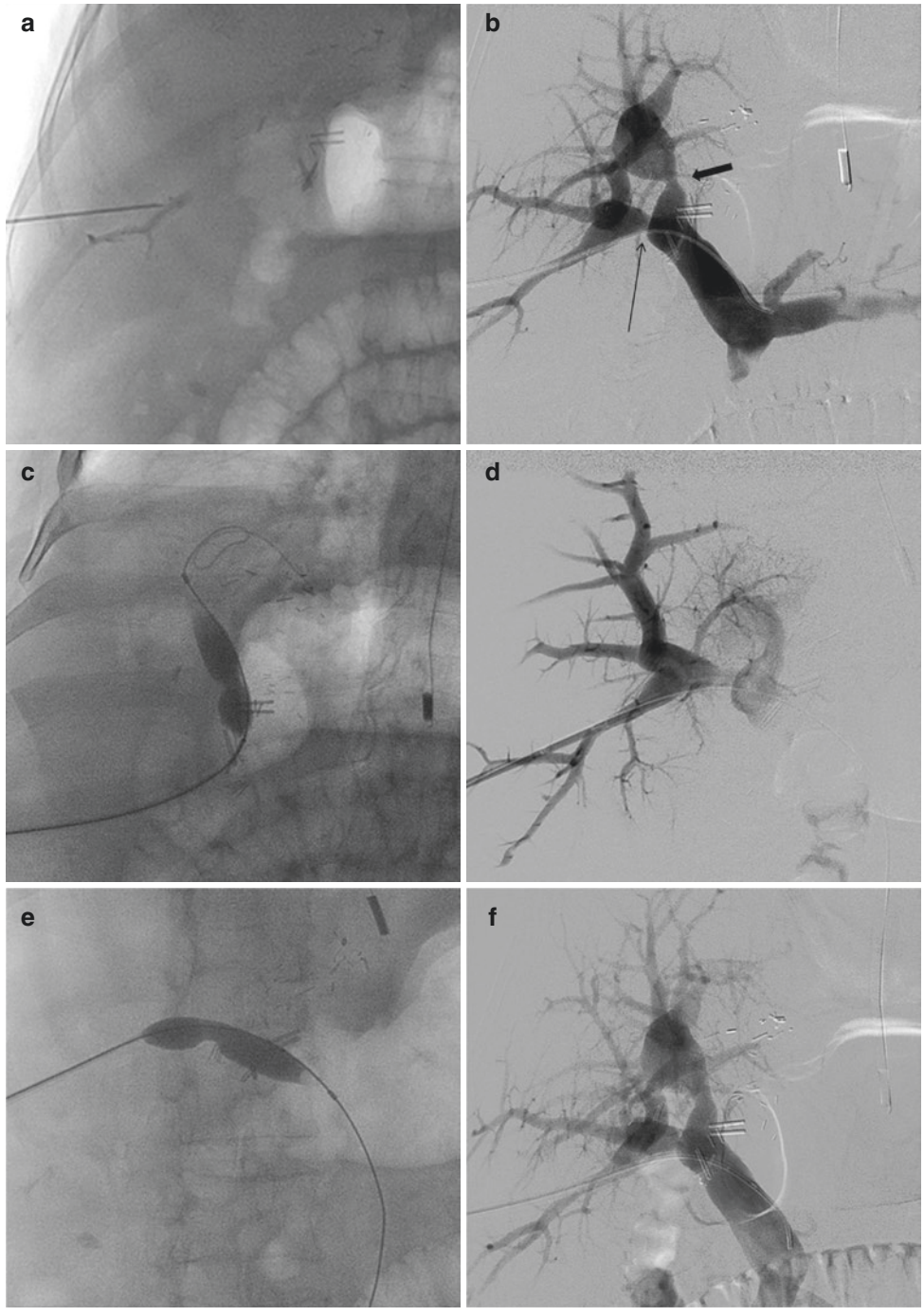

Fig. 17.4 (**a**) Ultrasound-guided puncture taken in a branch of right posterior portal vein supplying Segment 6. Contrast runs through the needle in fluoroscopy shows opacification of the branch. (**b**) Portogram is taken by placement of diagnostic catheter in the right portal vein via the access secured through trans-hepatic route in Segment 6 branch of the right posterior portal vein. Note the sites of portal vein stenosis in right anterior (short thick arrow) and right posterior (long thin arrow) portal vein branches distal to bifurcation. (**c**) Angioplasty/balloon dilatation of the right anterior portal vein stenosis. Note the neck in balloon which shows the site of stenosis. (**d**) Post dilatation check portogram shows opening up of right anterior portal vein stenosis. The stenosis in the right posterior portal vein branch is still noted. (**e**) Angioplasty/balloon dilatation of right posterior portal vein stenosis. Neck at the site of stenosis is noted while dilating the balloon. (**f**) Check portogram post-angioplasty shows opened up portal vein stenosis

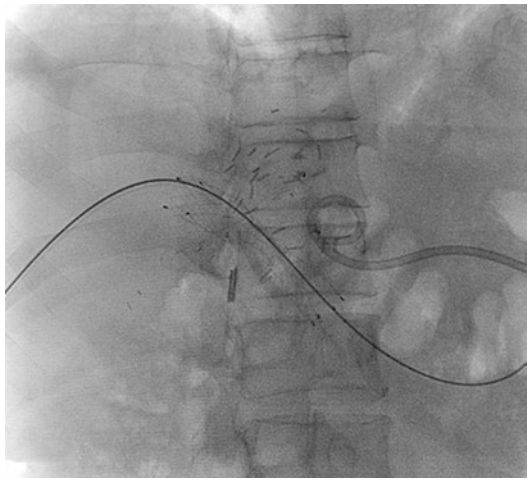

Fig. 17.5 Fluoroscopic image showing an uncovered stent deployed across the portal vein stenotic segment

surgical errors in anastomosis, whereas late complications are due to fibrosis or extrinsic compression from enlarged liver [73].

The diagnosis is made by DUS or CECT. The techniques to minimize the risk of development of vascular complications include anastomosis by piggyback or modified piggyback techniques. The piggyback technique involves resection of the recipient IVC and interposition of donor intrahepatic IVC with end-to-end anastomosis [74]. The modified piggyback technique involves using of three hepatic veins for anastomosis. This has been found to be related to fewer complications and hence is the preferred method of anastomosis [75].

Hepatic venous stenosis is specific to LDLT and has a reported incidence of 2 to 4% thereby leading to Budd–Chiari Syndrome.

The method of choice for management is by interventional radiological methods either by the transjugular approach (preferred) or transhepatic approach. Most of the cases are resolved by a single session of balloon angioplasty; however, multiple angioplasties may be required. Angioplasty with stent placement may also be a considerable option with a high success rate of 73% to 100% [76]. In cases of severe allograft dysfunction or multi-organ failure retransplantation is advised. The mortality rates of the patients with this complication stand high even though the abovementioned treatment options are available (11.1% with IR methods versus 41.6% with retransplantation) [73].

Endovascular Technique

The right IJV puncture is taken and access secured using a 6 Fr sheath. The stenosed hepatic vein is then accessed using 0.035-inch hydrophilic guidewire and Kumpe catheter and a venogram is taken to assess the severity of stenosis (Fig. 17.6a). The 0.035-inch hydrophilic guidewire is then exchanged with a super stiff Amplatz wire. The stenosis is dilated using a balloon catheter, 8 to 12 mm in diameter (Fig. 17.6b). This may be followed by stent placement (Fig. 17.6c). Stents of same diameter (8 to 12 mm) or 1 to 2 mm larger diameter are used. The length of the stent deployed is usually 4 cm. Post stent placement, balloon dilatation of the stent is done, if stenotic deformity of the stent is noted. This is followed by check venography to confirm the opening up of stenosis (Fig. 17.6d).

17.3.2.3 Splenic Steal/Portal Hyperperfusion (PHP) Syndrome

The incidence of this syndrome is approx. 4% and is a cause of graft ischemia [77]. This syndrome was earlier thought to be due to stealing of the blood flow of the hepatic artery by splenic artery due to portal hypertension and splenic hypertrophy. However, a recent theory suggests that increased portal venous flow (PHP) leads to decreased hepatic arterial flow and thus increases the flow in splenic artery [78].

The patient most commonly presents with deranged LFTs. If the presentation is late, features of portal hypertension are noted in the recipient. In the long term, this leads to arterial vasoconstriction causing complications such as biliary strictures and reperfusion injury [79]. The diagnosis is suggested by DUS findings. Angiography along with clinical suspicion and DUS findings leads to confirmation of PHP syndrome.

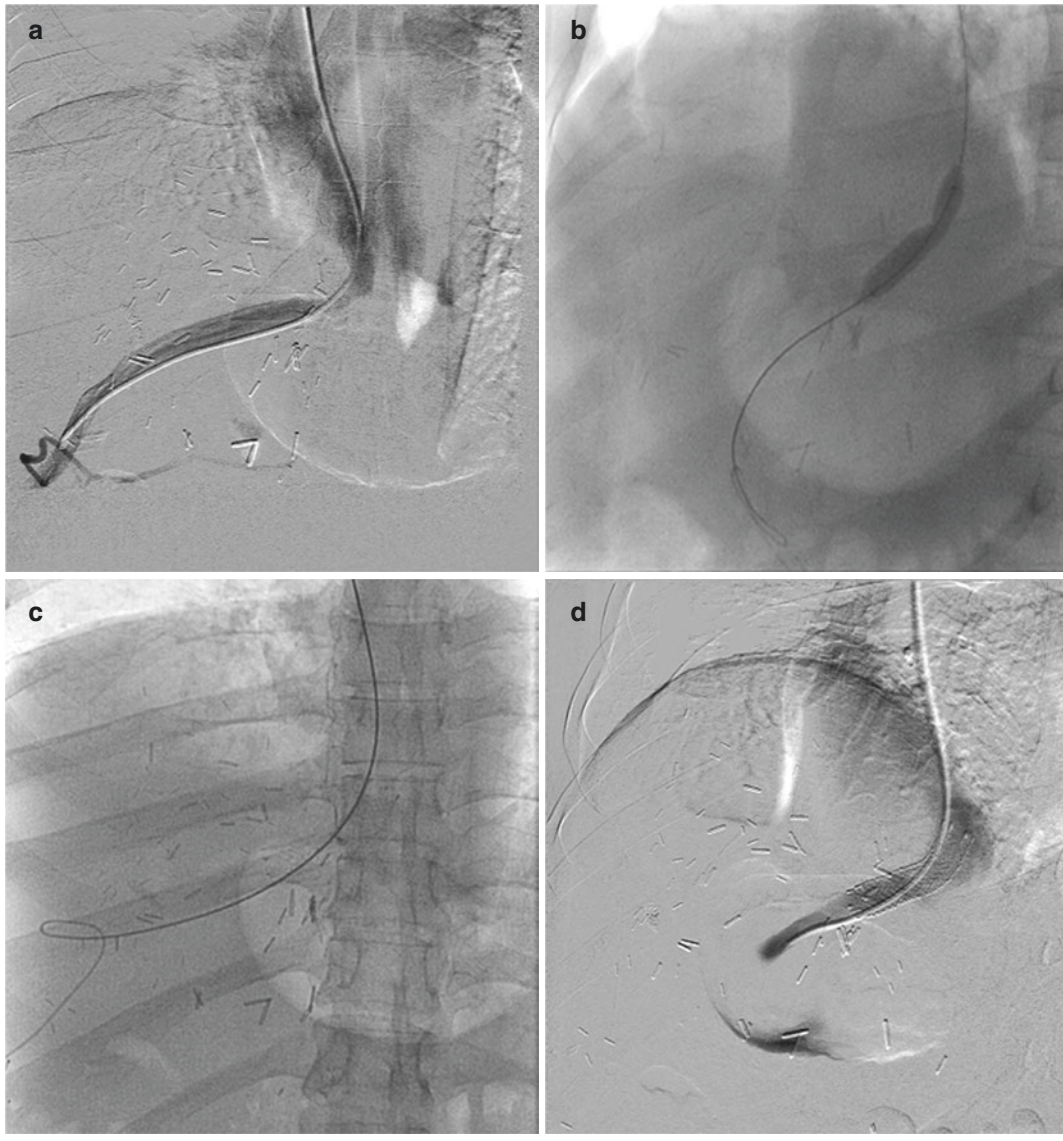

Fig. 17.6 (**a**) Right hepatic venogram through right jugular access shows mild stenosis at the site of anastomosis. (**b**) Fluoroscopic image shows balloon angioplasty of the stenotic segment being done. Note can be made of the neck in the balloon formed at the site of stenosis. (**c**) Uncovered stent placed across the site of stenosis after balloon angioplasty. (**d**) Check venogram shows improved flow across the previous stenotic site with resolution of stenosis after stent placement

Endovascular management is the preferred method of treatment. The motive of the treatment is to decrease the flow in the splenic artery leading to increased flow toward the transplanted liver. Proximal splenic artery embolization is performed since it maintains the distal collaterals and minimizes the risk of splenic infarction which can lead to abscess formation and eventually sepsis. The embolizing agents include coils or vascular plug. The surgical methods include splenic artery ligation, splenectomy, or mesocaval shunts [80].

17.3.3 Arterioportal Fistula (APF)

APF is known to have an association with biopsy or percutaneous cholangiography in a transplanted liver and is an uncommon finding [81]. These are usually asymptomatic and regress spontaneously. When symptomatic APF may present with hemobilia or graft ischemia. The diagnosis is made by DUS when the APF is large and symptomatic or by conventional angiography of hepatic arterial system.

The choice of management is endovascular and the preferred embolizing agent is coiled. The decision to intervene is based on the clinical scenario. If the APF is small and asymptomatic, close follow-up by regular imaging may be a considerable option. But this may be risky because if the APF becomes symptomatic or if it involves major hepatic arteries during this period, the risk of biliary ischemia post embolization increases. However early intervention in a small and asymptomatic posttransplant patient also involves the risk of hepatic artery dissection or thrombosis due to manipulation. Hence every patient with APF should be managed on case-to-case basis.

17.4 Conclusion

Hepatic transplantation is a life-saving measure for patients with end-stage liver disease. It is known to be associated with vascular complications in 7 to 11% cases. These complications can be a source of major morbidity to the patient eventually leading to graft loss and hence require prompt management. In recent times, the advances in interventional radiology have made it the first line of management in most of the cases. This treatment offers significant advantage to the patient being minimally invasive and a very low complication rate as compared to the open procedures. Hence, currently, interventional radiology plays an integral part of hepatic transplantation team along with transplant surgeons and hepatologists.

References

1. Khalaf H. Vascular complications after deceased and living donor liver transplantation: a single-center experience. Transplant Proc. 2010;42(3):865–70.
2. Wozney P, Zajko AB, Bron KM, Point S, Starzl TE. Vascular complications after liver transplantation: a 5-year experience. AJR Am J Roentgenol. 1986;147(4):657–63.
3. Karatzas T, Lykaki-Karatzas E, Webb M, Nery J, Tsaroucha A, Demirbas A, et al. Vascular complications, treatment, and outcome following orthotopic liver transplantation. Transplant Proc. 1997;29(7):2853–5.
4. Pawlak J, Grodzicki M, Leowska E, Malkowski P, Michalowicz B, Nyckowski P, et al. Vascular complications after liver transplantation. Transplant Proc. 2003;35(6):2313–5.
5. Duffy JP, Hong JC, Farmer DG, Ghobrial RM, Yersiz H, Hiatt JR, et al. Vascular complications of orthotopic liver transplantation: experience in more than 4,200 patients. J Am Coll Surg. 2009;208(5):896–903. Discussion–5
6. Perez-Saborido B, Pacheco-Sanchez D, Barrera-Rebollo A, Asensio-Diaz E, Pinto-Fuentes P, Sarmentero-Prieto JC, et al. Incidence, management, and results of vascular complications after liver transplantation. Transplant Proc. 2011;43(3):749–50.
7. Dodd GD 3rd, Memel DS, Zajko AB, Baron RL, Santaguida LA. Hepatic artery stenosis and thrombosis in transplant recipients: Doppler diagnosis with resistive index and systolic acceleration time. Radiology. 1994;192(3):657–61.
8. Crossin JD, Muradali D, Wilson SR. US of liver transplants: normal and abnormal. Radiographics. 2003;23(5):1093–114.
9. Stell D, Downey D, Marotta P, Solano E, Khakhar A, Quan D, et al. Prospective evaluation of the role of quantitative Doppler ultrasound surveillance in liver transplantation. Liver Transpl. 2004;10(9):1183–8.
10. Panaro F, Gallix B, Bouyabrine H, Ramos J, Addeo P, Testa G, et al. Liver transplantation and spontaneous neovascularization after arterial thrombosis: "the neovascularized liver". Transplant Int. 2011;24(9):949–57.
11. Pastacaldi S, Teixeira R, Montalto P, Rolles K, Burroughs AK. Hepatic artery thrombosis after orthotopic liver transplantation: a review of nonsurgical causes. Liver Transpl. 2001;7(2):75–81.
12. Silva MA, Jambulingam PS, Gunson BK, Mayer D, Buckels JA, Mirza DF, et al. Hepatic artery thrombosis following orthotopic liver transplantation: a 10-year experience from a single Centre in the United Kingdom. Liver Transpl. 2006;12(1):146–51.
13. Bekker J, Ploem S, de Jong KP. Early hepatic artery thrombosis after liver transplantation: a systematic review of the incidence, outcome and risk factors. American J Transpl. 2009;9(4):746–57.

14. Hejazi Kenari SK, Zimmerman A, Eslami M, Saidi RF. Current state of art management for vascular complications after liver transplantation. Middle East J Dig Dis. 2014;6(3):121–30.
15. Saad WE, Davies MG, Saad NE, Westesson KE, Patel NC, Sahler LG, et al. Catheter thrombolysis of thrombosed hepatic arteries in liver transplant recipients: predictors of success and role of thrombolysis. Vasc Endovasc Surg. 2007;41(1):19–26.
16. Singhal A, Stokes K, Sebastian A, Wright HI, Kohli V. Endovascular treatment of hepatic artery thrombosis following liver transplantation. Transplant Int. 2010;23(3):245–56.
17. Steinbruck K, Enne M, Fernandes R, Martinho JM, Balbi E, Agoglia L, et al. Vascular complications after living donor liver transplantation: a Brazilian, single-center experience. Transplant Proc. 2011;43(1):196–8.
18. Langnas AN, Marujo W, Stratta RJ, Wood RP, Shaw BW Jr. Vascular complications after orthotopic liver transplantation. Am J Surg. 1991;161(1):76–82. Discussion–3
19. Pareja E, Cortes M, Navarro R, Sanjuan F, Lopez R, Mir J. Vascular complications after orthotopic liver transplantation: hepatic artery thrombosis. Transplant Proc. 2010;42(8):2970–2.
20. Unal B, Gonultas F, Aydin C, Otan E, Kayaalp C, Yilmaz S. Hepatic artery thrombosis-related risk factors after living donor liver transplantation: single-center experience from Turkey. Transplant Proc. 2013;45(3):974–7.
21. Drazan K, Shaked A, Olthoff KM, Imagawa D, Jurim O, Kiai K, et al. Etiology and management of symptomatic adult hepatic artery thrombosis after orthotopic liver transplantation (OLT). Am Surg. 1996;62(3):237–40.
22. Bhattacharjya S, Gunson BK, Mirza DF, Mayer DA, Buckels JA, McMaster P, et al. Delayed hepatic artery thrombosis in adult orthotopic liver transplantation-a 12-year experience. Transplantation. 2001;71(11):1592–6.
23. Gunsar F, Rolando N, Pastacaldi S, Patch D, Raimondo ML, Davidson B, et al. Late hepatic artery thrombosis after orthotopic liver transplantation. Liver Transpl. 2003;9(6):605–11.
24. Margarit C, Hidalgo E, Lazaro JL, Murio E, Charco R, Balsells J. Biliary complications secondary to late hepatic artery thrombosis in adult liver transplant patients. Transplant Int. 1998;11(Suppl 1):S251–4.
25. Pungpapong S, Manzarbeitia C, Ortiz J, Reich DJ, Araya V, Rothstein KD, et al. Cigarette smoking is associated with an increased incidence of vascular complications after liver transplantation. Liver Transpl. 2002;8(7):582–7.
26. Panaro F, Ramos J, Gallix B, Mercier G, Herrero A, Niampa H, et al. Hepatic artery complications following liver transplantation. Does preoperative chemoembolization impact the postoperative course? Clin Transpl. 2014;28(5):598–605.
27. Marin-Gomez LM, Bernal-Bellido C, Alamo-Martinez JM, Porras-Lopez FM, Suarez-Artacho G, Serrano-Diaz-Canedo J, et al. Intraoperative hepatic artery blood flow predicts early hepatic artery thrombosis after liver transplantation. Transplant Proc. 2012;44(7):2078–81.
28. Fouzas I, Sklavos A, Bismpa K, Paxiadakis I, Antoniadis N, Giakoustidis D, et al. Hepatic artery thrombosis after orthotopic liver transplantation: 3 patients with collateral formation and conservative treatment. Transplant Proc. 2012;44(9):2741–4.
29. Abdelaziz O, Hosny K, Amin A, Emadeldin S, Uemoto S, Mostafa M. Endovascular management of early hepatic artery thrombosis after living donor liver transplantation. Transplant Int. 2012;25(8):847–56.
30. Figueras J, Busquets J, Dominguez J, Sancho C, Casanovas-Taltavull T, Rafecas A, et al. Intra-arterial thrombolysis in the treatment of acute hepatic artery thrombosis after liver transplantation. Transplantation. 1995;59(9):1356–7.
31. Vidjak V, Novacic K, Matijevic F, Kavur L, Slavica M, Mrzljak A, et al. Percutaneous endovascular treatment for hepatic artery stenosis after liver transplantation: the role of percutaneous endovascular treatment. Pol J Radiol. 2015;80:309–16.
32. Saad WE, Davies MG, Sahler L, Lee DE, Patel NC, Kitanosono T, et al. Hepatic artery stenosis in liver transplant recipients: primary treatment with percutaneous transluminal angioplasty. J Vasc Interv Radiol. 2005;16(6):795–805.
33. Abbasoglu O, Levy MF, Vodapally MS, Goldstein RM, Husberg BS, Gonwa TA, et al. Hepatic artery stenosis after liver transplantation--incidence, presentation, treatment, and long term outcome. Transplantation. 1997;63(2):250–5.
34. Sabri SS, Saad WE, Schmitt TM, Turba UC, Kumer SC, Park AW, et al. Endovascular therapy for hepatic artery stenosis and thrombosis following liver transplantation. Vasc Endovasc Surg. 2011;45(5):447–52.
35. Uller W, Knoppke B, Schreyer AG, Heiss P, Schlitt HJ, Melter M, et al. Interventional radiological treatment of perihepatic vascular stenosis or occlusion in pediatric patients after liver transplantation. Cardiovasc Intervent Radiol. 2013;36(6):1562–71.
36. Denys AL, Qanadli SD, Durand F, Vilgrain V, Farges O, Belghiti J, et al. Feasibility and effectiveness of using coronary stents in the treatment of hepatic artery stenoses after orthotopic liver transplantation: preliminary report. AJR Am J Roentgenol. 2002;178(5):1175–9.
37. Frongillo F, Grossi U, Lirosi MC, Nure E, Sganga G, Avolio AW, et al. Incidence, management, and results of hepatic artery stenosis after liver transplantation in the era of donor to recipient match. Transplant Proc. 2013;45(7):2722–5.
38. Orons PD, Sheng R, Zajko AB. Hepatic artery stenosis in liver transplant recipients: prevalence and cholangio-

graphic appearance of associated biliary complications. AJR Am J Roentgenol. 1995;165(5):1145–9.
39. Rostambeigi N, Hunter D, Duval S, Chinnakotla S, Golzarian J. Stent placement versus angioplasty for hepatic artery stenosis after liver transplant: a meta-analysis of case series. Eur Radiol. 2013;23(5):1323–34.
40. Boyvat F, Aytekin C, Harman A, Sevmis S, Karakayali H, Haberal M. Endovascular stent placement in patients with hepatic artery stenoses or thromboses after liver transplant. Transplant Proc. 2008;40(1):22–6.
41. Zhao DB, Shan H, Jiang ZB, Huang MS, Zhu KS, Chen GH, et al. Role of interventional therapy in hepatic artery stenosis and non-anastomosis bile duct stricture after orthotopic liver transplantation. World J Gastroenterol. 2007;13(22):3128–32.
42. Turrion VS, Alvira LG, Jimenez M, Lucena JL, Ardaiz J. Incidence and results of arterial complications in liver transplantation: experience in a series of 400 transplants. Transplant Proc. 2002;34(1):292–3.
43. Leelaudomlipi S, Bramhall SR, Gunson BK, Candinas D, Buckels JA, McMaster P, et al. Hepatic-artery aneurysm in adult liver transplantation. Transplant Int. 2003;16(4):257–61.
44. Volpin E, Pessaux P, Sauvanet A, Sibert A, Kianmanesh R, Durand F, et al. Preservation of the arterial vascularisation after hepatic artery pseudoaneurysm following orthotopic liver transplantation: long-term results. Ann Transplant. 2014;19:346–52.
45. Panaro F, Miggino M, Bouyabrine H, Carabalona JP, Berthet JP, Canaud L, et al. Reversed saphenous bypass for hepatic artery pseudoaneurysm after liver transplantation. Ann Vasc Surg. 2013;27(8):1088–97.
46. Fistouris J, Herlenius G, Backman L, Olausson M, Rizell M, Mjornstedt L, et al. Pseudoaneurysm of the hepatic artery following liver transplantation. Transplant Proc. 2006;38(8):2679–82.
47. Bonham CA, Kapur S, Geller D, Fung JJ, Pinna A. Excision and immediate revascularization for hepatic artery pseudoaneurysm following liver transplantation. Transplant Proc. 1999;31(1-2):443.
48. Boleslawski E, Bouras AF, Truant S, Liddo G, Herrero A, Badic B, et al. Hepatic artery ligation for arterial rupture following liver transplantation: a reasonable option. American J Transpl. 2013;13(4):1055–62.
49. Woo DH, Laberge JM, Gordon RL, Wilson MW, Kerlan RK Jr. Management of portal venous complications after liver transplantation. Tech Vasc Interv Radiol. 2007;10(3):233–9.
50. Orlandini M, Feier FH, Jaeger B, Kieling C, Vieira SG, Zanotelli ML. Frequency of and factors associated with vascular complications after pediatric liver transplantation. J Pediatr. 2014;90(2):169–75.
51. Schmitz V, Schoening W, Jelkmann I, Globke B, Pascher A, Bahra M, et al. Different cava reconstruction techniques in liver transplantation: piggyback versus cava resection. Hepatobiliary Pancreat Dis Int. 2014;13(3):242–9.
52. Buell JF, Funaki B, Cronin DC, Yoshida A, Perlman MK, Lorenz J, et al. Long-term venous complications after full-size and segmental pediatric liver transplantation. Ann Surg. 2002;236(5):658–66.
53. Sanchez-Bueno F, Hernandez Q, Ramirez P, Robles R, Acosta F, Rodriguez JM, et al. Vascular complications in a series of 300 orthotopic liver transplants. Transplant Proc. 1999;31(6):2409–10.
54. Lerut J, Tzakis AG, Bron K, Gordon RD, Iwatsuki S, Esquivel CO, et al. Complications of venous reconstruction in human orthotopic liver transplantation. Ann Surg. 1987;205(4):404–14.
55. Lee SJ, Kim KW, Kim SY, Park YS, Lee J, Kim HJ, et al. Contrast-enhanced sonography for screening of vascular complication in recipients following living donor liver transplantation. J Clin Ultrasound. 2013;41(5):305–12.
56. Lee H, Lim CW, Yoo SH, Koo CH, Kwon WI, Suh KS, et al. The effect of Doppler ultrasound on early vascular interventions and clinical outcomes after liver transplantation. World J Surg. 2014;38(12):3202–9.
57. Kensinger CD, Sexton KW, Baron CM, Lipnik AJ, Meranze SG, Gorden DL. Management of portal vein thrombosis after liver transplantation with a combined open and endovascular approach. Liver Transpl. 2015;21(1):132–4.
58. Liu FY, Wang MQ, Fan QS, Duan F, Wang ZJ, Song P. Interventional treatment for symptomatic acute-subacute portal and superior mesenteric vein thrombosis. World J Gastroenterol. 2009;15(40):5028–34.
59. Cherukuri R, Haskal ZJ, Naji A, Shaked A. Percutaneous thrombolysis and stent placement for the treatment of portal vein thrombosis after liver transplantation: long-term follow-up. Transplantation. 1998;65(8):1124–6.
60. Baccarani U, Gasparini D, Risaliti A, Vianello V, Adani GL, Sainz M, et al. Percutaneous mechanical fragmentation and stent placement for the treatment of early posttransplantation portal vein thrombosis. Transplantation. 2001;72(9):1572–82.
61. Lopez-Benitez R, Barragan-Campos HM, Richter GM, Sauer P, Mehrabi A, Fonouni H, et al. Interventional radiologic procedures in the treatment of complications after liver transplantation. Clin Transpl. 2009;23(Suppl 21):92–101.
62. Cavallari A, Vivarelli M, Bellusci R, Jovine E, Mazziotti A, Rossi C. Treatment of vascular complications following liver transplantation: multidisciplinary approach. Hepato-Gastroenterology. 2001;48(37):179–83.
63. Porrett PM, Hsu J, Shaked A. Late surgical complications following liver transplantation. Liver Transpl. 2009;15(Suppl 2):S12–8.
64. Guckelberger O, Bechstein WO, Langrehr JM, Kratschmer B, Loeffel J, Settmacher U, et al. Successful recanalization of late portal vein thrombosis after liver transplantation using systemic low-dose recombinant tissue plasminogen activator. Transplant Int. 1999;12(4):273–7.

65. Schneider N, Scanga A, Stokes L, Perri R. Portal vein stenosis: a rare yet clinically important cause of delayed-onset ascites after adult deceased donor liver transplantation: two case reports. Transplant Proc. 2011;43(10):3829–34.
66. Wei BJ, Zhai RY, Wang JF, Dai DK, Yu P. Percutaneous portal venoplasty and stenting for anastomotic stenosis after liver transplantation. World J Gastroenterol. 2009;15(15):1880–5.
67. Huang TL, Cheng YF, Chen TY, Tsang LL, Ou HY, Yu CY, et al. Doppler ultrasound evaluation of postoperative portal vein stenosis in adult living donor liver transplantation. Transplant Proc. 2010;42(3):879–81.
68. Shibata T, Itoh K, Kubo T, Maetani Y, Shibata T, Togashi K, et al. Percutaneous transhepatic balloon dilation of portal venous stenosis in patients with living donor liver transplantation. Radiology. 2005;235(3):1078–83.
69. Shiba H, Sadaoka S, Wakiyama S, Ishida Y, Misawa T, Yanaga K. Successful treatment by balloon angioplasty under portography for late-onset stenosis of portal vein after cadaveric liver transplantation. Int Surg. 2013;98(4):466–8.
70. Glanemann M, Settmacher U, Langrehr JM, Kling N, Hidajat N, Stange B, et al. Portal vein angioplasty using a transjugular, intrahepatic approach for treatment of extrahepatic portal vein stenosis after liver transplantation. Transplant Int. 2001;14(1):48–51.
71. Sanada Y, Kawano Y, Mizuta K, Egami S, Hayashida M, Wakiya T, et al. Strategy to prevent recurrent portal vein stenosis following interventional radiology in pediatric liver transplantation. Liver Transpl. 2010;16(3):332–9.
72. Navarro F, Le Moine MC, Fabre JM, Belghiti J, Cherqui D, Adam R, et al. Specific vascular complications of orthotopic liver transplantation with preservation of the retrohepatic vena cava: review of 1361 cases. Transplantation. 1999;68(5):646–50.
73. Darcy MD. Management of venous outflow complications after liver transplantation. Tech Vasc Interv Radiol. 2007;10(3):240–5.
74. Kishi Y, Sugawara Y, Matsui Y, Akamatsu N, Makuuchi M. Late onset portal vein thrombosis and its risk factors. Hepato-Gastroenterology. 2008;55(84):1008–9.
75. Cherqui D, Lauzet JY, Rotman N, Duvoux C, Dhumeaux D, Julien M, et al. Orthotopic liver transplantation with preservation of the caval and portal flows. Technique and results in 62 cases. Transplantation. 1994;58(7):793–6.
76. Lorenz JM, van Beek D, Funaki B, Van Ha TG, Zangan S, Navuluri R, et al. Long-term outcomes of percutaneous venoplasty and Gianturco stent placement to treat obstruction of the inferior vena cava complicating liver transplantation. Cardiovasc Intervent Radiol. 2014;37(1):114–24.
77. Saad WE. Nonocclusive hepatic artery hypoperfusion syndrome (splenic steal syndrome) in liver transplant recipients. Semin Interv Radiol. 2012;29(2):140–6.
78. Quintini C, Hirose K, Hashimoto K, Diago T, Aucejo F, Eghtesad B, et al. "splenic artery steal syndrome" is a misnomer: the cause is portal hyperperfusion, not arterial siphon. Liver Transpl. 2008;14(3):374–9.
79. Mogl MT, Nussler NC, Presser SJ, Podrabsky P, Denecke T, Grieser C, et al. Evolving experience with prevention and treatment of splenic artery syndrome after orthotopic liver transplantation. Transplant Int. 2010;23(8):831–41.
80. Troisi R, Ricciardi S, Smeets P, Petrovic M, Van Maele G, Colle I, et al. Effects of hemi-portocaval shunts for inflow modulation on the outcome of small-for-size grafts in living donor liver transplantation. American J Transpl. 2005;5(6):1397–404.
81. Saad WE, Davies MG, Rubens DJ, Sahler LG, Patel NC, Lee DE, et al. Endoluminal management of arterioportal fistulae in liver transplant recipients: a single-center experience. Vasc Endovasc Surg. 2006;40(6):451–9.

18 Interventions in Post-Liver Transplant Settings: Biliary Complication Management

Swati Das and Amar Mukund

18.1 Introduction

With the evolution and advancement in medical science orthotopic liver transplantation (LT) has become an established treatment for patients with advanced liver disease. Refinements, as well as expertise in surgical techniques, improved immunosuppressive agents and evolution of endoscopic as well as radiological interventional procedures, have allowed 1 year graft and patient survival rates of 80–95% and 5-Year rates of 60–85% [1].

As with any complex surgery different types of complications are also found in case of liver transplantation. The most common source of posttransplant complication in a liver transplant patient is the biliary tract [2, 3].

Since the last two decades, there has been an increase in graft and patient survival secondary to effective endoscopic treatment and percutaneous radiological interventions in managing the biliary complications. Surgery is reserved only for refractory cases or having a complex biliary anatomy [4].

To understand the type of complication as well as to plan the protocol for management of the complication proper knowledge of the surgical anatomy of the biliary anastomosis is essential along with a recent magnetic resonance cholangiopancreatography (MRCP) [5].

18.2 Indications for Interventions in Posttransplant Biliary Complications

1. Asymptomatic patients with elevated liver enzymes on routine follow-up without evidence of rejection on liver biopsy.
2. Patients with jaundice, pruritus with or without anorexia.
3. Patients with cholangitis presenting as fever, jaundice, with or without pain abdomen.
4. Suspicious output from biliary drain.

Currently, initial modality for management of patients with such presentation is endoscopic retrograde cholangiopancreatography (ERCP). Percutaneous procedures are reserved for patients with Roux en Y hepatico jejunostomy (RYHJ) or in patients with failed ERCP [4].

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18.3 Contraindications for Percutaneous Radiological Interventions

18.3.1 Absolute Contraindication

Uncontrolled bleeding diathesis.

18.3.2 Relative Contraindications

1. INR > 1.5
2. Platelet counts <50,000/cc
3. Ascites

18.4 Procedural Technique

18.4.1 Management of Biliary Stricture

Percutaneous transhepatic biliary drainage (PTBD) is indicated if there is failure or infeasibility of ERCP. MRCP review is often useful in demonstrating the number, location, and configuration of anastomosis (Fig. 18.1) along with the surgical notes describing the anastomosis [5].

Prior to the procedure, history of any antiplatelet or anticoagulant drug intake needs to be checked and if any should be stopped 5 to 7 days

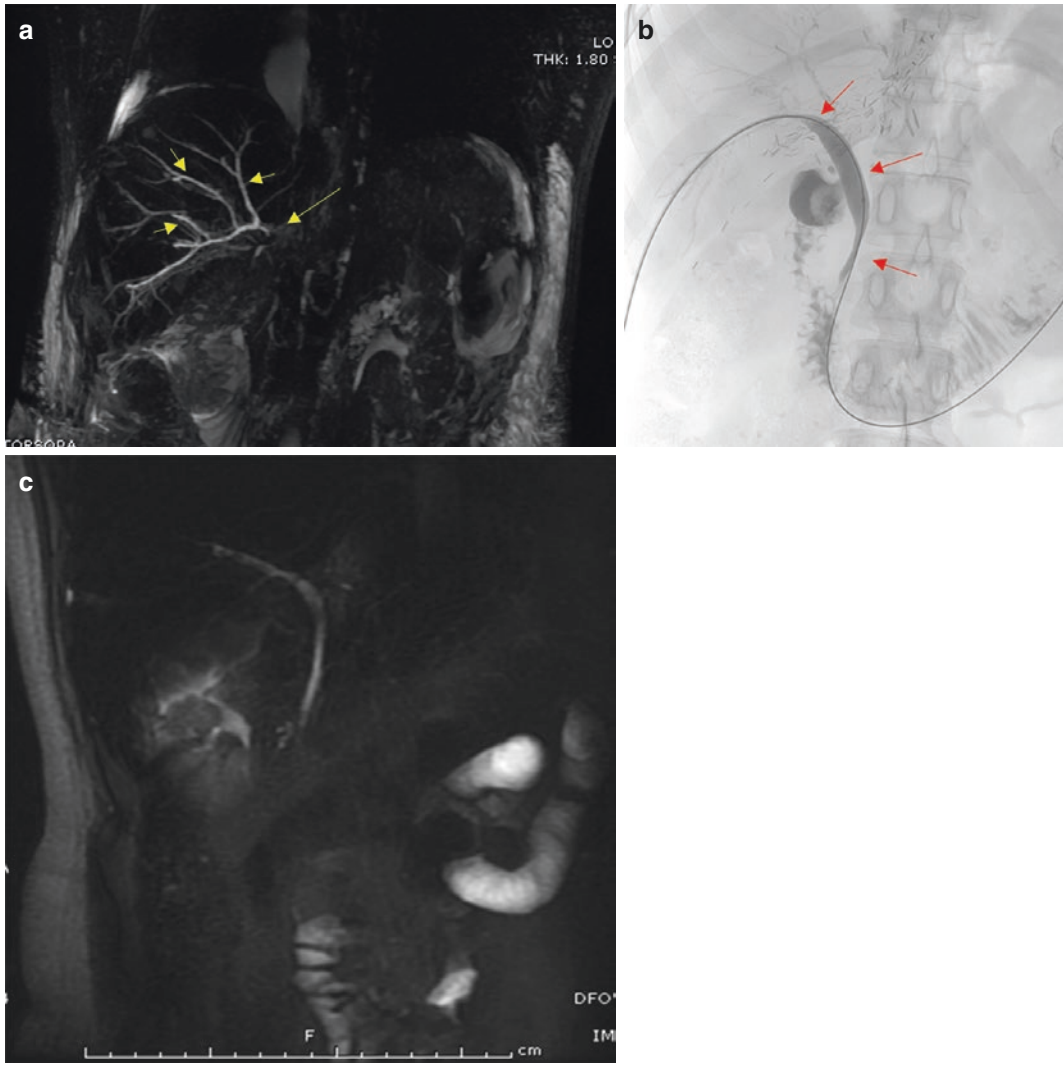

Fig. 18.1 (**a**) Stricture (long arrow) at anastomosis of right hepatic duct of graft and common bile duct of recipient in a patient of right lobe living donor liver transplant. Resultant mild right lobar biliary radicle dilatation (Short arrows). (**b**) Percutaneous transhepatic access followed by balloon dilatation of the stricture (arrows). (**c**) Follow up MRCP shows resolution of the anastomotic stricture as well as the biliary radicle dilatation. (Source: ILBS, New Delhi, PACS)

before the procedure or exchanged with low molecular weight heparin. Platelet count should be above 50,000/cc and the International normalized ratio (INR) should be maintained above 1.5. Prophylactic antibiotics prior to the procedure and immunosuppressant should be stopped on the day of procedure, at least 6 h of the empty stomach with intravenous (IV) fluid infusion are prerequisites.

It is usually performed under sedation. Most often the intrahepatic biliary radicles are minimally dilated in post-transplant patients with biliary complications. So, PTBD is carried using a 22G Chiba needle and 0.018 inch guidewire (NEFF set, COOK, Bloomington, IN). After puncture of biliary radicle, 0.018 inch wire is replaced with a 0.035 inch wire using a dilator. The combination of hydrophilic flexible 0.035 guidewire and angled catheter (KMP/MPA, COOK Bloomington, IN) is used to cross the stricture. If internal drainage is not possible then 7/8/10F external drain is placed for decompression of biliary system and resolution of inflammation. Subsequently internalization can be planned in next 3 to 7 days. After successful internalization 7/8/10 F internal–external biliary drainage catheter should be placed until resolution of stricture. The stricture needs to be dilated with a balloon of size that exceeds the normal ductal calibre by approximately 10% (Fig. 18.1). Some authors recommend prolonged balloon inflation for 20 minutes and multiple repeat procedure (2–3 times) within 2 weeks to achieve a durable result. In our institution 8 mm to 12 mm diameter balloons are used for a period of 3 to 5 minutes and repeated 3 weekly until resolution of stricture (Fig. 18.1). In some institutions cutting balloons are used to incise the dense fibrous tissue of the stricture [6].

The hardware required for PTBD is given in Table 18.1.

Plastic stents can be inserted via a rendezvous endoscopic procedure. In patients requiring repeated interventions percutaneous insertion of retrievable covered self-expanding metallic stents remain a viable option.

Table 18.1 Standard hardware list for PTBD

NEFF set (COOK)	22 G Chiba needle, 0.018 guide wire, 6F dilator (multiple dilator assembly)
J tip hydrophilic guide wire (Terumo)	0.035 inch, 150/260 cm
Kumpe (KMP)/BMC catheter (COOK)	5/6 Fr
J tip external biliary catheter	7 Fr/8/10 Fr
Non-compliant balloon	8 mm/10 mm/ 12 mm x 4 cm

Patients with biliary complications associated with hepatic artery thrombosis (HAT) are managed by surgery when occur within 1 week [7].

18.4.1.1 Technical Challenges

A. Failure of internalization because of the presence of acute angulation between donor and recipient bile ducts or complete obstruction or severe stenosis [4].

18.4.1.2 Alternative Techniques

1. Magnetic compression anastomosis (MCA): In this technique, through percutaneous approach one magnet is placed to the proximal site of stricture and another magnet is placed distal to the stricture endoscopically. The diameter of magnet is up to 4 to 5 mm and the approximation of which causes necrosis of the intervening tissue and creates a pathway to traverse guidewire. The recurrence rates of stricture managed by this technique are lower than that after stent placement. However, longer length of stricture, tortuous shape of bile ducts, the parallel orientation of proximal and distal ducts result in improper approximation of the magnets resulting in treatment failure [4].
2. External drainage of biliary system followed by a revision biliary reconstruction with HJ.

B. Inadvertent puncture of a ligated biliary channel which leads to failure of internalization and lifelong placement of external biliary drain. It can be avoided by prior knowledge of the type of ductal anastomosis and review of the MRCP to detect such biliary channels beforehand.

18.4.1.3 Management of Bile Leak

Bile leaks are managed by percutaneous drainage of the biloma. Bile leak may lead to the development of biliary stricture which can be managed by endoscopic or percutaneous biliary diversion [7].

In case of large leak, open surgical RYHJ may be required. In those cases, PTBD can be helpful in creating RYHJ. The PTBD catheter can be used as a guide to find the duct for the anastomosis with the Roux limb of jejunum.

18.4.1.4 Management of Stones and Sludge

Endoscopic removal is the first line of management. In cases of failure or non-feasibility of ERCP or patients with extensive intrahepatic stones, percutaneous removal may be tried [7].

Under USG guidance the affected duct is punctured and an access sheath is placed. The first step is to look for any biliary stricture, which should be addressed, if present. Later the stone extraction balloon is used over the wire to push the stones into the small bowel. For hard stones, dormia baskets may be used to break the stones using a sheath.

Impacted intrahepatic duct stones and biliary casts cannot be removed by balloon maceration or snares or baskets. For them, percutaneous transhepatic cholangioscopy (PTCS) is required [8]. First PTBD using 8.5 Fr internal–external catheter is performed. After 2 to 3 days the tract was dilated with a large (16/18 Fr) catheter. The catheter was placed 10 to 14 days before PTCS. After tract maturation PTCS was performed using 5.2 mm diameter cholangioscope. The stones and casts can be macerated and removed using mechanical basket lithotripsy while for stones larger than 2 cm electrohydraulic lithotripsy is used.

The management protocol for posttransplant biliary complications is given in Fig. 18.2.

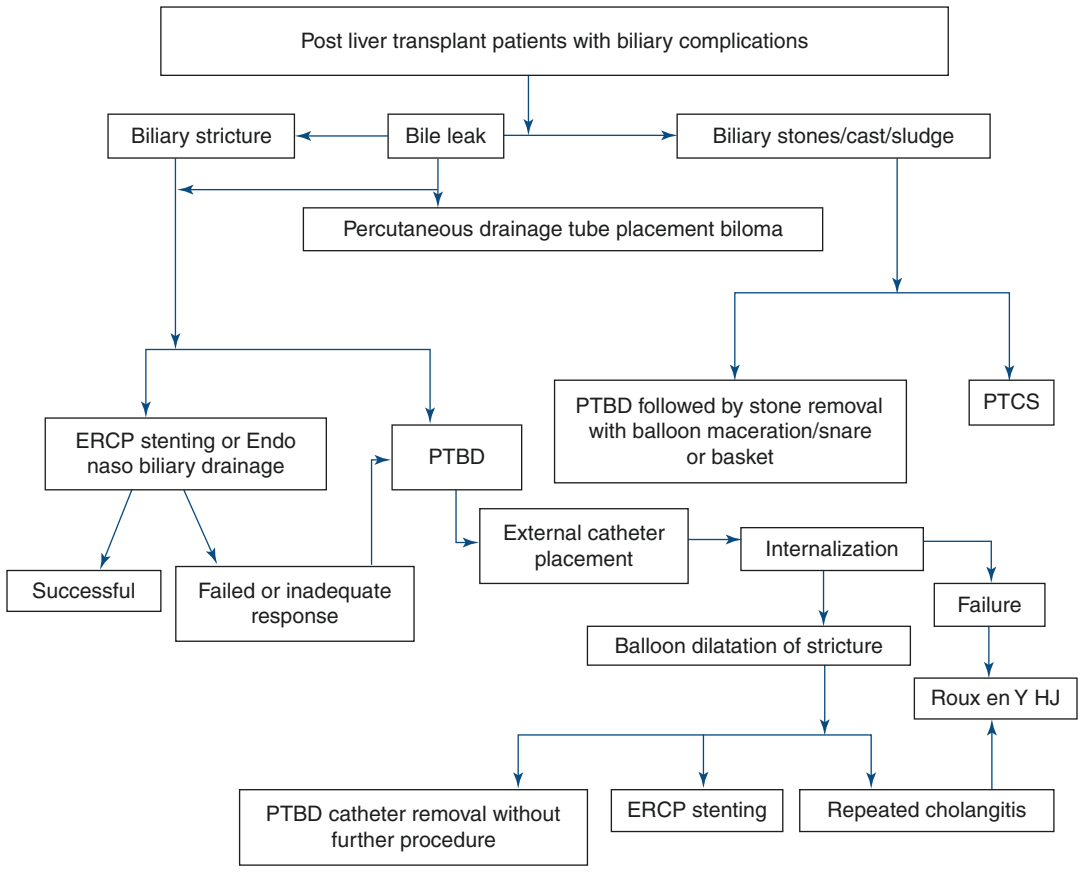

Fig. 18.2 Management protocol of posttransplant biliary complications

18.4.1.5 Technical Success of Treatment of Biliary Stricture

It is defined as resolution of intrahepatic biliary dilatation with free flow of contrast across the bile duct into the duodenum or jejunum without stenosis.

18.4.1.6 Technical Success of Treatment of Bile Leak

It is defined as a resolution of contrast leak from the bile duct.

18.4.1.7 Clinical Success

It is defined as the resolution of jaundice and other symptoms of cholangitis.

18.4.1.8 Complications

The most common complications encountered after PTBD are tube displacement and peritubal leak. Others are infection, hemobilia, pseudoaneurysm or injury of hepatic artery, arterioportal fistula, portal venous thrombosis, and pancreatitis [5].

18.5 Discussion

18.5.1 Spectrum of Biliary Complications

Various studies have shown that the incidence of post-liver transplantation biliary complication is about 10–30%, which is more common in the patients undergoing living donor liver transplant (LDLT) (30%) than dead donor liver transplant (DDLT) (10%) [9–11]. Multiple reconstructions, small calibre peripheral ducts to make anastomosis, devascularisation of bile ducts during hilar dissection are the factors contributing to the increased incidence of biliary complications after LDLT [12–14]. It is also more common in right lobe graft than left lobe graft. It is likely due to the different anatomical orientation and length of the right and left hepatic ducts as well as the different blood supply [14].

The different types of biliary complications that are encountered in posttransplant patients are biliary stricture, bile leak, biloma, biliary stones, sludge or casts sphincter of Oddi dysfunction due to denervation of ampulla [15, 16]. Biliary stricture is most common and makes about 40–60% of the biliary complications. It can be of two types that is anastomotic stricture (AS) and non-anastomotic stricture (NAS) in which the former is more common [4]. Bile leak consists of 2–25% cases. Rest of the complications amount to a lesser percentage of cases [17].

18.5.2 Risk Factors of Biliary Complications

The donor or graft related factors: Donor age (Higher age), ABO incompatibility, donation after cardiac death, extended donor criteria, prolonged cold, or warm ischemia time, prior performance of transarterial chemoembolization (TACE) for hepatocellular carcinoma.

The surgical factors: Excessive dissection of periductal tissue, excessive electro cauterisation, bile leaks, small calibre bile ducts, disparity between donor and recipient duct.

Post-surgical factors: HAT, CMV (Cyto Megalo Virus) infection, rejection.

18.6 Treatment Options for Biliary Complications

Biliary Stricture: It is the most common type of complication. It can be classified as AS and NAS. AS is short, isolated, and occurs within 5 mm of biliary anastomosis. They usually present within 1 year after LT [18]. Technical factors, bile leak, etc. are the causes for development of AS. The initial modality of choice for the treatment of AS is ERCP. Patients with failed ERCP are managed by PTBD and resistant cases by surgery [17]. NAS is longer, multiple, more proximally located. Commonly encountered causes are HAT, increase cold ischemia time, ABO incompatibility. It occurs earlier than AS with a mean time to stricture development of 3 to 6 months [19]. Endoscopic therapy is also initial

modality of treatment for NAS but results are less satisfactory [20]. PTBD is an alternative but require multiple interventions. 50% require retransplantation [19].

In case of AS the predictors of difficult and poor outcome of endoscopic management are as follows [5, 21]:

1. Multiple duct anastomosis/ductoplasty.
2. Anastomosis near hilum close to secondary biliary confluence.
3. Late onset or delayed diagnosis of biliary stricture resulting in more tight/fibrous stricture.
4. Narrow or separate duct type stricture.
5. Pouched or round shape of distal duct tip.
6. Sharp acute angulation of the proximal and distal anastomotic bile ducts.

Hisatsune et al. [22] has classified the anastomosis into 4 types according to the configuration. They are fork type, triangular, intermediate, and pouched type. Among which pouched type has higher failure rates with ERCP.

Pasha et al. [23] have found that early stricture presenting within 1 month has a high ERCP success rate while late stricture has less ERCP success rate because of the fibrotic nature of the later. So, these difficult types of strictures as well as those with RYHJ may be managed by PTBD initially. PTBD in comparison with endoscopy is relatively more invasive with a higher incidence of complication like hemorrhage, peritubal leak, need to keep an external catheter that is liable to be displaced. Very few studies have compared ERCP and PTBD head to head. The results of this study showed similar success and complication rates for both ERCP and PTBD [24].

In the study by Wadhawan et al. [25] technical success rate of ERCP was 75%, PTBD was the salvage procedure to manage majority of the failures. The success rate reaches upto 91% in the cases managed by both PTBD and ERCP. Rarely, both ERCP and PTBD fail (about 9%). In those cases surgical intervention like Roux en Y HJ or retransplantation is required.

Few studies [5, 26] have shown high efficacy and safety of PTBD as a first-line therapy in patients where ERCP is infeasible as well as a salvage procedure in those endoscopic treatment failed for management of post-liver transplant biliary complication.

MCA is a new treatment modality in case of completely obstructed biliary stricture. A recent literature review has shown recanalization can be achieved in 88% of patients with duct to duct anastomotic stricture using MCA [27].

Kim ES et al. [28] have found PTBD to be successful in treating bile duct anastomosis stricture in 60% of patients, but taking into account repeated sessions of PTBD the success rate reached up to 87%. In this study upsizing up to 12 F to 14 F catheter was done and in a follow-up cholangiogram usually, after a period of 2 to 6 months, if the stricture was resolved, removal of catheter was done.

Bile Leak: It is the next most common post-transplant biliary complication after biliary stricture and is the earliest (less than 3 months) post LT complication [29]. It can be classified as early or late according to its onset before or after 1 month from LT [17]. Some studies have found that bile leaks occurring within 1 month of the posttransplant period are usually at the anastomotic site and are mostly related to technical issues or hepatic artery stenosis or thrombosis. While bile leaks occurring after 1 month of post-transplant period mostly from the T tube insertion site because of delay in maturation of T tube tract.

It has been found that the prevalence of bile leaks does not differ according to the living or dead donor liver transplantation [30] and also according to the type of anastomosis (duct to duct or HJ) [18]. But a study by Kulkarni et al. has revealed that the number of anastomosis is directly proportional to bile leak rate [31]. Single duct to duct anastomosis in right lobe graft has shown a lower incidence of leakage as compared to other anastomotic types. But at the same time this group has been found to be associated with a more incidence of stricture [12, 32].

The sites for bile leaks to arise can be variable but most commonly from the anastomosis; however other less commonly encountered sites can be the cystic duct remnant, the cut surface of the liver, or the T tube tract. The patients may be asymptomatic or present as abdominal pain. The patients with pain abdomen, ascites, and peritoneal signs need surgical intervention. Similarly,

patients with large bile leaks from isolated ducts would mostly need surgical repair [7]. Bile leak patients, other than those mentioned above should get imaging (MRCP) for diagnosis, PCD (percutaneous drainage) for the biloma and ERCP as a therapy to treat bile leak (sphincterotomy and biliary stenting) which yields a high success rate [33]. PTBD is done as rescue treatment for patients with failed ERCP or as a guide for surgical reconstructions [7].

Biliary Stones and Sludge: It is the third common posttransplant biliary complication after biliary stricture and bile leak with incidence of 5% [17]. The usual time of appearance of bile duct stones is at a median of one and half years after liver transplantation and that of casts is usually within 1 year after transplantation [21]. Biliary obstruction, ischemia, infection, cholesterol super saturation, cyclosporine, etc. can lead to biliary stone or sludge formation [34]. They can be asymptomatic or can present with pain abdomen and features of cholangitis [17].

For patients with non-altered anatomy, endoscopic approach allows sphincterotomy and stone removal using an extraction balloon or extraction basket [34]. The patients in whom ERCP is not feasible or failed because of extensive intrahepatic stones PTBD followed by stone removal is the proposed treatment [7]. And in those with intractable stricture PTCS is considered the treatment of choice [17].

18.6.1 Sphincter of Oddi Dysfunction

It is seen in 2–7% of patients who undergo LT [17]. Surgical intervention leads to oedema or stenosis or denervation of ampulla resulting in a hypertonic sphincter. Endoscopic biliary sphincterotomy has a high success rate (80–100%) [17].

18.7 Advanced Equipment in Managing Biliary Complications

Peripheral cutting balloon is useful in the treatment of resistant fibrous and tight biliary strictures [6]. Paclitaxel eluting balloon is used as a new treatment for biliary anastomotic stricture because of its anti-proliferative property [21]. Covered self-expanding metal with anti-migrating waist to combat migration stent and a long retrievable string can be used in patients with recurrent stricture [21].

18.8 Management of Biliary Complications in Donors

There is a low rate of occurrence of biliary complications in living liver donors with an incidence of about 2.5 to 15%. It has been found that bile leak is the most common complication in this group [35]. It is seen more commonly in the cases who have donated the right lobe [36]. Biliary stricture occurs less frequently as compared to those in recipients [37]. The general principles and protocol of management in donors are similar to those of recipients both endoscopically or percutaneously and the results are also similar as well [38].

18.9 Management of Biliary Complications after Paediatric Liver Transplantation

The incidence of biliary complications in pediatric patients following transplantation is 20-40% [39] with the incidence of biliary stricture about 5–35% and of bile leak about 6–20% [40]. It is more prevalent in paediatric population because of small calibre of ducts and vascular strictures [21]. Since RYHJ is the most common type of biliary anastomosis in paediatric patients endoscopy is difficult to perform in these cases. So, percutaneous treatment like PTBD or PCD constitutes a minimal invasive and useful alternative to surgical revision [39, 41]. The management consists of percutaneous access and internal–external catheter (6–12Fr) placement with or without balloon dilatation (5–7 mm). A study by R. Miraglia et al. has revealed that percutaneous balloon dilatation had good results, although prolonged treatment with multiple sessions of dilatations over several months is necessary to obtain the cure of the stricture [39].

18.10 Conclusion

Biliary tract complications remain an important cause of morbidity and mortality after liver transplantation. The endoscopic as well as percutaneous radiological interventions both are effective and should be considered complementary in the treatment of biliary complications. In case of duct to duct anastomosis endoscopy is considered first line while for RYHJ radiological intervention is considered first line. Using these minimally invasive procedures further surgery can be avoided and patient survival will be better.

References

1. Ioannou GN. Development and validation of a model predicting graft survival after liver transplantation. Liver Transpl. 2006 Nov;12(11):1594–606.
2. Akamatsu N, Sugawara Y, Hashimoto D. Biliary reconstruction, its complications and management of biliary complications after adult liver transplantation: a systematic review of the incidence, risk factors and outcome. Transpl Int. 2011 Apr;24(4):379–92.
3. Perrakis A, Förtsch T, Schellerer V, Hohenberger W, Müller V. Biliary tract complications after orthotopic liver transplantation: still the "Achilles heel"? Transplant Proc. 2010 Dec;42(10):4154–7.
4. Koksal AS, Eminler AT, Parlak E, Gurakar A. Management of biliary anastomotic strictures after liver transplantation. Transplant Rev (Orlando). 2017 Jul;31(3):207–17.
5. Mukund A, Choudhury A, Das S, Pamecha V, Sarin SK. Salvage PTBD in post living donor liver transplant patients with biliary complications-a single Centre retrospective study. Br J Radiol. 2020 Apr;93(1108):20191046. https://doi.org/10.1259/bjr.20191046.
6. Saad WE, Davies MG, Saad NE, Waldman DL, Sahler LG, Lee DE, Kitanosono T, Sasson T, Patel NC. Transhepatic dilation of anastomotic biliary strictures in liver transplant recipients with use of a combined cutting and conventional balloon protocol: technical safety and efficacy. J Vasc Interv Radiol. 2006 May;17(5):837–43.
7. Lorenz JM. The role of interventional radiology in the multidisciplinary Management of Biliary Complications after liver transplantation. Tech Vasc Interv Radiol. 2015 Dec;18(4):266–75.
8. Nam K, Lee SK, Song TJ, Park DH, Lee SS, Seo DW, Kim MH. Percutaneous transhepatic cholangioscopy for biliary complications after liver transplantation: a single center experience. J Hepatobiliary Pancreat Sci. 2016 Oct;23(10):650–7.
9. Yazumi S, Chiba T. Biliary complications after a right-lobe living donor liver transplantation. J Gastroenterol. 2005 Sep;40(9):861–5.
10. Verdonk RC, Buis CI, Porte RJ, van der Jagt EJ, Limburg AJ, van den Berg AP, Slooff MJ, Peeters PM, de Jong KP, Kleibeuker JH, Haagsma EB. Anastomotic biliary strictures after liver transplantation: causes and consequences. Liver Transpl. 2006 May;12(5):726–35.
11. Mosca S, Militerno G, Guardascione MA, Amitrano L, Picciotto FP, Cuomo O. Late biliary tract complications after orthotopic liver transplantation: diagnostic and therapeutic role of endoscopic retrograde cholangiopancreatography. J Gastroenterol Hepatol. 2000 Jun;15(6):654–60.
12. Gondolesi GE, Varotti G, Florman SS, Muñoz L, Fishbein TM, Emre SH, Schwartz ME, Miller C. Biliary complications in 96 consecutive right lobe living donor transplant recipients. Transplantation. 2004 Jun 27;77(12):1842–8.
13. Ishiko T, Egawa H, Kasahara M, Nakamura T, Oike F, Kaihara S, Kiuchi T, Uemoto S, Inomata Y, Tanaka K. Duct-to-duct biliary reconstruction in living donor liver transplantation utilizing right lobe graft. Ann Surg. 2002 Aug;236(2):235–40.
14. Hwang S, Lee SG, Sung KB, Park KM, Kim KH, Ahn CS, Lee YJ, Lee SK, Hwang GS, Moon DB, Ha TY, Kim DS, Jung JP, Song GW. Long-term incidence, risk factors, and management of biliary complications after adult living donor liver transplantation. Liver Transpl. 2006 May;12(5):831–8.
15. Arain MA, Attam R, Freeman ML. Advances in endoscopic management of biliary tract complications after liver transplantation. Liver Transpl. 2013 May;19(5):482–98.
16. Tarantino I, Barresi L, Petridis I, Volpes R, Traina M, Gridelli B. Endoscopic treatment of biliary complications after liver transplantation. World J Gastroenterol. 2008 Jul 14;14(26):4185–9.
17. Balderramo D, Navasa M, Cardenas A. Current management of biliary complications after liver transplantation: emphasis on endoscopic therapy. Gastroenterol Hepatol. 2011 Feb;34(2):107–15.
18. Greif F, Bronsther OL, Van Thiel DH, Casavilla A, Iwatsuki S, Tzakis A, Todo S, Fung JJ, Starzl TE. The incidence, timing, and management of biliary tract complications after orthotopic liver transplantation. Ann Surg. 1994 Jan;219(1):40–5.
19. Thethy S, Thomson BN, Pleass H, Wigmore SJ, Madhavan K, Akyol M, Forsythe JL, James Garden O. Management of biliary tract complications after orthotopic liver transplantation. Clin Transpl. 2004 Dec;18(6):647–53.
20. Yazumi S, Yoshimoto T, Hisatsune H, Hasegawa K, Kida M, Tada S, Uenoyama Y, Yamauchi J, Shio S, Kasahara M, Ogawa K, Egawa H, Tanaka K, Chiba T. Endoscopic treatment of biliary complications after right-lobe living-donor liver transplantation with duct-to-duct biliary anastomosis. J Hepato-Biliary-Pancreat Surg. 2006;13(6):502–10.

21. Shin M, Joh JW. Advances in endoscopic management of biliary complications after living donor liver transplantation: comprehensive review of the literature. World J Gastroenterol. 2016 Jul 21;22(27):6173–91.
22. Hisatsune H, Yazumi S, Egawa H, Asada M, Hasegawa K, Kodama Y, Okazaki K, Ito K, Takakuwa H, Tanaka K, Chiba T. Endoscopic management of biliary strictures after duct-to-duct biliary reconstruction in right-lobe living-donor liver transplantation. Transplantation. 2003 Sep 15;76(5):810–5.
23. Pasha SF, Harrison ME, Das A, Nguyen CC, Vargas HE, Balan V, Byrne TJ, Douglas DD, Mulligan DC. Endoscopic treatment of anastomotic biliary strictures after deceased donor liver transplantation: outcomes after maximal stent therapy. Gastrointest Endosc. 2007 Jul;66(1):44–51.
24. Lee SH, Ryu JK, Woo SM, Park JK, Yoo JW, Kim YT, Yoon YB, Suh KS, Yi NJ, Lee JM, Han JK. Optimal interventional treatment and long-term outcomes for biliary stricture after liver transplantation. Clin Transpl. 2008 Jul-Aug;22(4):484–93.
25. Wadhawan M, Kumar A, Gupta S, Goyal N, Shandil R, Taneja S, Sibal A. Post-transplant biliary complications: an analysis from a predominantly living donor liver transplant center. J Gastroenterol Hepatol. 2013 Jun;28(6):1056–60.
26. Hung HH, Chen TS, Tseng HS, Hsia CY, Liu CS, Lin HC, Loong CC. Percutaneous transhepatic cholangiography and drainage is an effective rescue therapy for biliary complications in liver transplant recipients who fail endoscopic retrograde cholangiopancreatography. J Chin Med Assoc. 2009 Aug;72(8):395–401.
27. Okajima H, Kotera A, Takeichi T, Ueno M, Ishiko T, Hirota M, Asonuma K, Yamauchi E, Inomata Y. Magnet compression anastomosis for bile duct stenosis after duct-to-duct biliary reconstruction in living donor liver transplantation. Liver Transpl. 2005 Apr;11(4):473–5.
28. Kim ES, Lee BJ, Won JY, Choi JY, Lee DK. Percutaneous transhepatic biliary drainage may serve as a successful rescue procedure in failed cases of endoscopic therapy for a post-living donor liver transplantation biliary stricture. Gastrointest Endosc. 2009 Jan;69(1):38–46.
29. Shamsaeefar A, Nikeghbalian S, Kazemi K, Motazedian N, Geramizadeh B, Malekhosseini SA. Thirteen-year evaluation of the Management of Biliary Tract Complication after deceased donor liver transplantation. Prog Transplant. 2017 Jun;27(2):192–5.
30. Kochhar G, Parungao JM, Hanouneh IA, Parsi MA. Biliary complications following liver transplantation. World J Gastroenterol. 2013 May 21;19(19):2841–6.
31. Kulkarni CB, Prabhu NK, Kader NP, Rajeshkannan R, Pullara SK, Moorthy S. Percutaneous transhepatic techniques for management of biliary anastomotic strictures in living donor liver transplant recipients. Indian J Radiol Imaging. 2017 Jan-Mar;27(1):92–9.
32. Kasahara M, Egawa H, Takada Y, Oike F, Sakamoto S, Kiuchi T, Yazumi S, Shibata T, Tanaka K. Biliary reconstruction in right lobe living-donor liver transplantation: comparison of different techniques in 321 recipients. Ann Surg. 2006 Apr;243(4):559–66.
33. Dumonceau JM, Tringali A, Blero D, Devière J, Laugiers R, Heresbach D, Costamagna G. European Society of Gastrointestinal Endoscopy. Biliary stenting: indications, choice of stents and results: European Society of Gastrointestinal Endoscopy (ESGE) clinical guideline. Endoscopy. 2012 Mar;44(3):277–98.
34. Lee HW, Shah NH, Lee SK. An update on endoscopic Management of Post-Liver Transplant Biliary Complications. Clin Endosc. 2017 Sep;50(5):451–63.
35. Wang SF, Huang ZY, Chen XP. Biliary complications after living donor liver transplantation. Liver Transpl. 2011 Oct;17(10):1127–36.
36. Shio S, Yazumi S, Ogawa K, Hasegawa K, Tsuji Y, Kida M, Yamauchi J, Ida H, Tada S, Uemoto S, Chiba T. Biliary complications in donors for living donor liver transplantation. Am J Gastroenterol. 2008 Jun;103(6):1393–8.
37. Chang JH, Lee I, Choi MG, Han SW. Current diagnosis and treatment of benign biliary strictures after living donor liver transplantation. World J Gastroenterol. 2016 Jan 28;22(4):1593–606.
38. Hasegawa K, Yazumi S, Egawa H, Tamaki H, Asada M, Kodama Y, Hisatsune H, Okazaki K, Tanaka K, Chiba T. Endoscopic management of postoperative biliary complications in donors for living donor liver transplantation. Clin Gastroenterol Hepatol. 2003 May;1(3):183–8.
39. Miraglia R, Maruzzelli L, Caruso S, Riva S, Spada M, Luca A, Gridelli B. Percutaneous management of biliary strictures after pediatric liver transplantation. Cardiovasc Intervent Radiol. 2008 Sep-Oct;31(5):993–8.
40. Heffron TG, Pillen T, Welch D, Smallwood GA, Redd D, Romero R. Biliary complications after pediatric liver transplantation revisited. Transplant Proc. 2003 Jun;35(4):1461–2.
41. Uller W, Wohlgemuth WA, Hammer S, et al. Percutaneous treatment of biliary complications in pediatric patients after liver transplantation. Fortschr Rontgenstr. 2014;186:1127–33.