Indian J Surg (September–October 2013) 75(5):339–345
DOI 10.1007/s12262-012-0712-4

REVIEW ARTICLE

Non-Operative Management of Hepatic Trauma and the Interventional Radiology: An Update Review

Bruno Monteiro Tavares Pereira

Received: 24 May 2012 / Accepted: 18 July 2012 / Published online: 3 August 2012

Abstract The growing trend to manage hepatic injuries nonoperatively has been increasing demand for advanced endovascular interventions. This brings up the necessity for general and trauma surgeons to update their knowledge in such matter. Effective treatment mandates a multispecialty team effort that is usually led by the trauma surgeon and includes vascular surgery, orthopedics, and, increasingly, interventional radiology. The focus on hemorrhage control and the angiographer's unique access to vascular structures gives interventional radiology (IR) an important and increasingly recognized role in the treatment of patients with hemodynamic instability. Our aim is to review the basic concepts of IR primarily in hepatic trauma and secondarily in some other special situations. A liver vascular anatomy review is also needed for better understanding the roles of IR. As a final point we propose a guideline for the operative/nonoperative management of traumatic hepatic injuries. The benefit of multidisciplinary approach (TAE) appears to be a powerful weapon in the medical arsenal against the high mortality of injured trauma liver patients.

Keyword Hepatic trauma · Interventional radiology · Non-operative management of hepatic trauma · Angioembolization

B. M. T. Pereira
Division of Trauma Surgery, Department of Surgery, School of Medical Sciences (FCM), University of Campinas (UNICAMP), Campinas, SP, Brazil

B. M. T. Pereira
Faculty of the Division of Trauma Surgery, School of Medicine—University of Campinas—UNICAMP, Campinas, Brazil

B. M. T. Pereira (✉)
UNICAMP,
181 Rua Alexander Fleming,
13.083-970 Campinas, SP, Brazil
e-mail: drbrunomonteiro@hotmail.com

Introduction

The growing trend to manage hepatic injuries nonoperatively has been increasing demand for advanced endovascular interventions [1–4]. This brings up the necessity for general and trauma surgeons to update their knowledge in such matter.

Effective treatment mandates a multispecialty team effort that is usually led by the trauma surgeon and includes vascular surgery, orthopedics, and, increasingly, interventional radiology [5, 6]. The focus on hemorrhage control and the angiographer's unique access to vascular structures gives interventional radiology (IR) an important and increasingly recognized role in the treatment of patients with hemodynamic instability.

Our aim is to review the basic concepts of IR primarily in hepatic trauma and secondarily in some other special situations. A liver vascular anatomy review is also needed for better understanding the roles of IR. As a final point we propose a guideline for the operative/nonoperative management of traumatic hepatic injuries.

History

Charles Dotter dreamt up IR in the early 1960s and first officially declared about it on June 19, 1963, at the Czechoslovak Radiological Congress (Czech Republic). In his more than 1-hour speech, *Cardiac Catheterization and Angiographic Techniques of the Future*, he discussed, among other topics, catheter biopsy, controlled exit catheterization, occlusion catheterization for various purposes, and the rationale of catheter endarterectomy [7–10] (Table 1).

Interventional Radiology

Nowadays, interventional radiology (IR) can treat many trauma conditions that once required surgery, non-operatively [1].

Table 1 The history and the evolution of Embolization

History of interventional radiology
1973 Embolization for pelvic trauma
1974 Transhepatic embolization for variceal bleeding
1977-83 Bland- and chemo-embolization for treatment of hepatocellular cancer and disseminated liver metastases
1980's Biliary stents to allow bile to flow from the liver saving patients from biliary bypass surgery
1981 Embolization technique for spleen trauma
1982 TIPS (transjugular intrahepatic portosystemic shunt) to improve blood flow in damaged livers from conditions such as cirrhosis and hepatitis C
1990 Radiofrequency ablation (RFA) technique for liver tumors
1990's Treatment of bone and kidney tumors by embolization
1990's RFA for soft tissue tumors, i.e., bone, breast, kidney, lung and liver cancer
1997 Intra-arterial delivery of tumor-killing viruses and gene therapy vectors to the liver
1999 Percutaneous delivery of pancreatic islet cells to the liver for transplantation to treat diabetes

The interventional radiologists started developing endoscopic procedures on the liver in 1974 and on trauma in 1973 for pelvic hemorrhages.

Using real-time imaging, the specialist guides the catheter through the artery and then releases clotting agents into the blood vessels, slowing the blood flow and stopping the hemorrhage from the inside out.

In another way, interventional radiologists can inflate a balloon inside the artery just like in angioplasty, to stop the bleeding and stabilize the patient so that the surgeon can treat the wound. Often with massive hemorrhage, there is so much blood coming at the surgeon that it is impossible for him/her to see the wound from the outside in order to repair it. Since interventional radiologists visualize what they are doing from the inside of the vessel using imaging, they can see the blood supply, stop the bleeding, and pinpoint the location of the wound for the surgeon or for embolization treatment [11–13].

The management of foremost hepatic trauma persists to advance. Formerly, mortality rates as high as 50–80 % have been reported for severe hepatic injury [14]. Mortality rates are highest in patients with injuries to the hepatic veins and retrohepatic vena cava and in those presenting in shock requiring emergent laparotomy [15]. In the 1970s, hepatic packing emerged as an effective adjunct for hemorrhage control and has been used extensively since the advent of damage control laparotomy (DCL).

The theory of damage control was developed in an effort to improve outcome in patients with vascular and multi-organ injuries. The rationale for damage control is that, although control of hemorrhage and contamination is necessary, the time required for formal resections and reconstruction may aggravate the cycle of coagulopathy, acidosis, and hypothermia [16].

Asensio et al. [5, 13, 17] reported mortality rates as low as 8–22 % for severe hepatic trauma (AAST-OIS over grade III). These improved patient outcomes have been achieved with the use of both angio-embolization (AE) and DCL in patients with complex hepatic trauma [18]. The benefits of AE in a multimodality approach to hepatic trauma have been demonstrated; however, the morbidity associated with the use of AE and the subsequent liver-related complications have yet to be fully elucidated [19].

Liver Anatomy

Liver anatomy has not changed with time; however, it is very important to make a quick review of it before talking about its management [20].

There are many anatomical and functional descriptions of the liver anatomy. In the classical description, the external appearance of the liver is used to describe the anatomy. However, there are many differences between this classical model and the functional models, as popularized by Couinaud.

Correspondingly to the Couinaud model, the liver can be divided in eight functionally independent segments, which are related to the portal network ramifications. Each segment has its own vascular inflow, outflow, and biliary drainage [21].

Because of this division into self-contained units, each can be accessed by IR or even resected without damaging those remaining. In the centre of each segment, there is a branch of the portal vein, hepatic artery, and bile duct. In the periphery of each segment, there is a vascular outflow through the hepatic veins [22].

For the liver to remain viable, resections must proceed along the vessels that define the peripheries of these segments. In general, this means resection lines parallel the hepatic veins while preserving the portal veins, bile ducts, and hepatic arteries that provide vascular inflow and biliary drainage through the centre of the segment [23].

The common hepatic artery is one of the three major branches of the celiac axis. After giving off the gastroduodenal artery, the main hepatic artery continues and divides into the right and left hepatic arteries. The portal vein divides into the right and left branches. Three major hepatic veins drain into the IVC in 70 % of cases, but in the remaining 30 % accessory veins occur [21, 23–25].

Hepatic Trauma

Blunt or penetrating trauma may lead to intraparenchymal laceration and hematoma, subcapsular hematoma, or capsular

rupture with intraperitoneal hemorrhage. Intraparenchymal lacerations and hematomas are usually elliptical or linear in shape. In recent years there has been a trend toward more conservative management of liver trauma, with less surgical intervention [26]. Imaging plays an important role in the assessment of the nature and extent of hepatic trauma except where the injuries are immediately life-threatening and require emergency surgery. Information regarding the type of lesion and its anatomical location in relation to the major hilar structures and the confluence of the hepatic veins and IVC can be rapidly obtained and used to guide subsequent management.

Asensio and contributors [5, 13] described the complex hepatic injuries (grades IV and V) as highly lethal. In one study regarding multidisciplinary approach, they presented 75 patients who sustained penetrating (63 %) and blunt (37 %) injuries. Authors demonstrated the overall survival as 69 %; adjusted survival excluding patients requiring emergency department thoracotomy was 76 %. Authors showed the benefit of angiography and angioembolization as indicated: 12 % mortality among those who received it versus 36 % mortality among those who did not ($P=0.074$). After all Asensio et al. conclude that the multidisciplinary approach to the management of these severe grades of injuries appears to improve survival in these highly lethal injuries.

In another series of 103 patients [13], the authors also account that improvements in mortality can be achieved with an appropriate operative approach and as an adjunct procedure the angioembolization decreases mortality in AAST-OIS grades IV and V hepatic injuries. This study included patients with a mean injury severity score of 33± 9.5. Mechanism of injury was penetrating in 79 % and blunt in 21 %. Adjusted overall survival rate after emergency department thoracotomy patients were excluded was 58 %.

Velmahos et al. [27, 28] report that nonoperative management of liver injuries is safe and effective regardless of the grade of liver injury.

The management of gunshot injuries to the abdomen has remained unchanged for many decades, with mandatory laparotomy being the standard practice. However, this concept has been challenged and some centers with extensive experience with penetrating injuries practice a selective nonoperative management [29, 30]. Demetriades and colleagues [29] reported the selective nonoperative management for gunshot injuries to the liver. During a 42-month period, a total of 928 patients were admitted with abdominal gunshot injuries, 16 % of whom had a liver injury. The authors demonstrated a pool of 52 patients (34 % of all liver injuries) in whom the liver was the only injured intra-abdominal organ. Overall, the authors conclude that selected patients with isolated grades I and II gunshot wounds to the liver can be managed nonoperatively. Selective nonoperative management of penetrating abdominal solid organ injuries looks to be safe and effective even when performed in combat casualties [30–32].

The integration of interventional radiologic procedures, particularly angioembolization, represents a logical extension of modern damage control techniques [19]. About 50 % of stab wounds to the anterior abdomen and about 85 % of stab wounds to the posterior abdomen can safely be managed nonoperatively.

A stable AAST liver grade II or III patient is a good example where angioembolism can be successfully used in either adults or children [30, 33–35].

Complications after transcatheter arterial embolization (TAE) include delayed hemorrhage, hepatic necrosis, infection/sepsis, and biliary fistula. These are usually found via abnormal physical findings on abdominal CT or ultrasonography. Fever is a common sign, occurring in as many as 69 % of patients who have TAE [36, 37].

The flow chart represents a guideline proposal for the operative/nonoperative management of the hepatic trauma (Fig. 1).

Vascular Interventional Techniques

Vascular interventional techniques in the liver can be divided into the following broad categories:

1. Hepatic arterial embolization
2. Hepatic arterial infusion techniques
3. Portal vein embolization
4. Transjugular intrahepatic portosystemic stent shunt (TIPSS) insertion
5. Hepatic venous intervention

Hepatic Arterial Embolization (Control of Hemorrhage)

Hepatic arterial bleeding may occur into the biliary tree, into the hepatic parenchyma, or into the peritoneal space, and most commonly occurs as a result of accidental trauma; other causes include neoplastic disease and arteritis such as polyarteritis nodosa. Arterial hemorrhage is often extremely difficult to manage surgically, as simple ligation of the main hepatic artery (which is often all that can be performed at operation) will frequently fail to control bleeding due to the extensive collateral arterial supply that exists in the liver [36]. A percutaneous angiographic technique, on the other hand, allows selective catheterization and occlusion of the abnormal vessel in the majority of cases, and this should be the procedure of first choice in most instances [38].

Selective arterial artery embolization for liver traumatic injuries has been described since 1977 [39]. Once a source of hemorrhage has been identified, the aim should be to

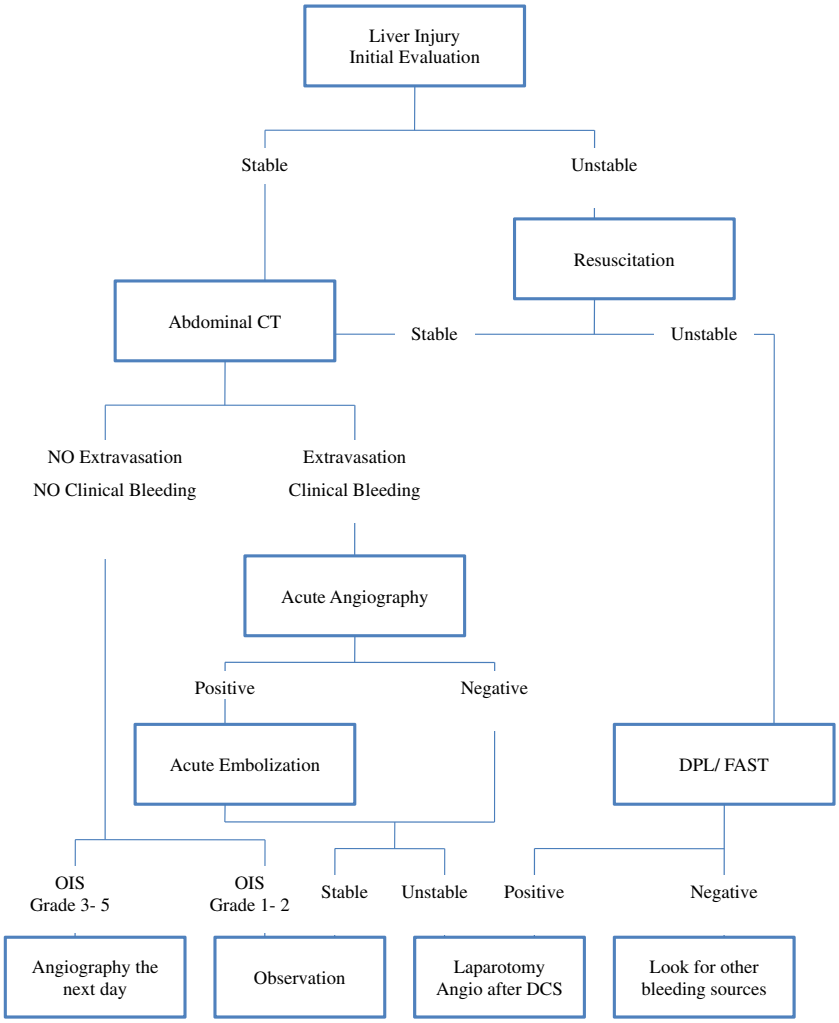

Fig. 1 Guideline proposal for the operative/ non operative management of the hepatic trauma

isolate the abnormality from the hepatic arterial tree, if this is possible. This requires selective catheterization and occlusion of the vessel beyond the arterial injury first, and then its occlusion more proximally. In many instances this procedure will require the use of a coaxial catheter (one that passes through the central lumen of the diagnostic catheter). Embolization is usually performed with metallic coils. In the majority of cases, surgery is avoided [40–42].

Special Situations: Tumor Embolization

The majority of liver tumors, whether primary or secondary, derive most of their blood supply from branches of the hepatic artery, with little or no supply from the portal vein. The portal vein, on the other hand, provides 70 % or more of the blood reaching the liver and can deliver a considerable proportion of its oxygen supply. It is possible, therefore, to render a hepatic tumor largely ischemic by occluding its arterial supply, while the surrounding normal liver parenchyma remains well perfused by portal blood (provided of course that the portal venous inflow to the liver is not compromised). This technique has gained widespread acceptance as a useful palliative treatment of HCC and metastatic neuroendocrine tumors. Both of these neoplasms are usually highly vascular and will thus often respond well to this form of therapy [43].

Hepatic Arterial Infusion Techniques

The infusion of chemotherapeutic agents into the liver via the hepatic artery or the portal vein, in order to deliver a higher concentration of chemotherapeutic agent, can be safely achieved via an IV route to treat metastatic disease or primary HCC. There has been resurgence of interest in intra-arterial therapy because of the ability of radiologists to place, percutaneously, long-term indwelling hepatic arterial catheters. The technique involves the selective catheterization, via a femoral or axillary artery puncture, of the hepatic artery to be infused with a suitable long-term catheter, which is then attached to a subcutaneous port into which the medication to be infused is injected [40, 41].

Portal Vein Embolization

The main indications for embolization of the portal vein are to induce hepatic lobar hypertrophy and to treat certain liver tumors; the latter is usually combined with hepatic arterial embolization.

Patients with hepatic tumors who would otherwise not be surgical candidates because of an insufficient volume of normal liver to allow resection may benefit from embolization of the portal vein supplying the tumor-containing lobe. This produces significant hypertrophy of the contralateral hepatic lobe and has proved to be both safe and effective, especially in those individuals with a small left lobe who require a right, or extended right, hepatic resection [44–47].

Although rare and often a fatal condition in surgical patients, portal vein air embolization after blunt trauma has already been described with clinically benign course and spontaneous resolution [48, 49].

Transjugular Portosystemic Stent Shunt

TIPSS involves the creation of a track between the portal vein and one of the hepatic veins, followed by insertion of a stent to maintain its patency. It is often life-saving in patients with acute visceral hemorrhage who have not responded to emergency endoscopic sclerotherapy, and this remains its major indication [50, 51]. Other clinical situations in which TIPSS placement may be useful include severe abdominal ascites due to liver disease that is resistant to medical therapy, Budd–Chiari syndrome (BCS) and hepatorenal syndrome [52, 53].

Hepatic Venous Intervention

The major indication for hepatic venous intervention is the investigation and treatment of BCS. In patients with stable liver function, the surgical fashioning of a portosystemic shunt has been advocated as the most appropriate treatment option. However, patients who have short-segment occlusions of the hepatic veins or IVC may be successfully managed by angioplasty. Bypassing IVC and intrahepatic venous occlusions is not always straightforward, and may require approaches from a combination of transjugular, transfemoral, and transhepatic routes. In those patients in whom it is not possible to restore hepatic venous drainage due to either impassable intrahepatic occlusions or extensive venous thrombosis, TIPSS insertion may provide an alternative to surgical shunting. This procedure has two advantages over the alternative of a surgical shunt: first, it does not compromise subsequent hepatic transplantation should this become necessary; and, second, it bypasses the caval stenosis that is commonly present in patients with BCS due to associated caudate lobe hypertrophy [54–56].

Conclusion

The advances in modern street armamentarium and the cumulative amount of wounds per patient, linked with improved prehospital care, have resulted in more severely injured patients arriving alive to urban trauma centers.

Rolling hemorrhage after damage control laparotomy remains a most challenging problem. In the postoperative period, it is often difficult to differentiate active hemorrhage of parenchymal vessels from the nonmechanical, coagulopathic bleeding commonly faced in this population of patients. In supplement, an urgent return to the OR for re-exploration represents a terrific re-insult on a patient who is often at the lowest point of physiologic reserve. The benefit of multidisciplinary approach (TAE) appears to be a powerful weapon in the medical arsenal against the high mortality of injured trauma liver patients.

Nonoperative management of hepatic trauma is becoming the standard of care in many trauma centers worldwide. Knowledge on IR adds an important advantage in the set of options when treating these severe lesions.

References

1. Zealley IA, Chakraverty S (2010) The role of interventional radiology in trauma. BMJ 340:c497
2. Shaftan GW (2008) How interventional radiology changed the practice of a trauma surgeon. Injury 39(11):1229–1231
3. Gould JE, Vedantham S (2006) The role of interventional radiology in trauma. Semin Intervent Radiol 23(3):270–248
4. Pryor JP, Braslow B, Reilly PM, Gullamondegi O, Hedrick JH, Schwab CW (2005) The evolving role of interventional radiology in trauma care. J Trauma 59(1):102–104
5. Asensio JA, Petrone P, Garcia-Nunez L, Kimbrell B, Kuncir E (2007) Multidisciplinary approach for the management of complex hepatic injuries AAST-OIS grades IV-V: a prospective study. Scand J Surg 96(3):214–220
6. Sriussadaporn S, Pak-art R, Tharavej C, Sirichindakul B, Chiamananthapong S (2002) A multidisciplinary approach in the management of hepatic injuries. Injury 33(4):309–315
7. Bakal CW (2003) Advances in imaging technology and the growth of vascular and interventional radiology: a brief history. J Vasc Interv Radiol 14(7):855–860
8. Kononov A, Egorova VA (2000) Interventional radiology: history, priorities, first experimental results. Klinichna khirurhiia / Ministerstvo okhorony zdorov'ia Ukrainy, Naukove tovarystvo khirurhiv Ukrainy. Klin Khir 3:47–51
9. Zeitler E (1995) History of interventional radiology. Radiologe 35 (5):325–336
10. Rosch J, Keller FS, Kaufman JA (2003) The birth, early years, and future of interventional radiology. J Vasc Interv Radiol 14(7):841–853

11. De Toma G, Mingoli A, Modini C, Cavallaro A, Stipa S (1994) The value of angiography and selective hepatic artery embolization for continuous bleeding after surgery in liver trauma: case reports. J Trauma 37(3):508–511
12. Fandrich BL, Gnanadev DA, Jaecks R, Boyle W (1989) Selective hepatic artery embolization as an adjunct to liver packing in severe hepatic trauma: case report. J Trauma 29(12):1716–1718
13. Asensio JA, Roldan G, Petrone P, Rojo E, Tillou A, Kuncir E et al (2003) Operative management and outcomes in 103 AAST-OIS grades IV and V complex hepatic injuries: trauma surgeons still need to operate, but angioembolization helps. J Trauma 54(4):647–653, discussion 53–54
14. Mohr AM, Lavery RF, Barone A, Bahramipour P, Magnotti LJ, Osband AJ et al (2003) Angiographic embolization for liver injuries: low mortality, high morbidity. J Trauma 55(6):1077–1081, discussion 81–82
15. Sikhondze WL, Madiba TE, Naidoo NM, Muckart DJ (2007) Predictors of outcome in patients requiring surgery for liver trauma. Injury 38(1):65–70
16. Rotondo MF, Schwab CW, McGonigal MD, Phillips GR III, Fruchterman TM, Kauder DR et al (1993) 'Damage control': an approach for improved survival in exsanguinating penetrating abdominal injury. J Trauma 35(3):375–382, discussion 82–83
17. Asensio JA, Demetriades D, Chahwan S, Gomez H, Hanpeter D, Velmahos G et al (2000) Approach to the management of complex hepatic injuries. J Trauma 48(1):66–69
18. Yitzhak A, Shaked G, Lupu L, Mizrahi S, Kluger Y (2001) Selective embolization of hepatic arteries—an additional precaution to control hemorrhage in the management of severe liver trauma. Harefuah 140(3):193–196, 288
19. Johnson JW, Gracias VH, Gupta R, Guillamondegui O, Reilly PM, Shapiro MB et al (2002) Hepatic angiography in patients undergoing damage control laparotomy. J Trauma 52(6):1102–1106
20. Longmire WP Jr, Cleveland RJ (1972) Surgical anatomy and blunt trauma of the liver. Surg Clin North Am 52(3):687–698
21. Skandalakis JE, Skandalakis LJ, Skandalakis PN, Mirilas P (2004) Hepatic surgical anatomy. Surg Clin North Am 84(2):413–435, viii
22. Gadzijev EM (2002) Surgical anatomy of hepatoduodenal ligament and hepatic hilus. J Hepatobiliary Pancreat Surg 9(5):531–533
23. Sharma D, Deshmukh A, Raina VK (2001) Surgical anatomy of retrohepatic inferior vena cava and hepatic veins: a quantitative assessment. Indian journal of gastroenterology. Indian J Gastroenterol 20(4):136–139
24. Jones RM, Hardy KJ (2001) The hepatic artery: a reminder of surgical anatomy. J Royal Coll Surg Edinburgh 46(3):168–170
25. van Leeuwen MS, Noordzij J, Fernandez MA, Hennipman A, Feldberg MA, Dillon EH (1994) Portal venous and segmental anatomy of the right hemiliver: observations based on three-dimensional spiral CT renderings. Am J Roentgenol 163 (6):1395–1404
26. Trunkey DD (2004) Hepatic trauma: contemporary management. Surg Clin North Am 84(2):437–450
27. Velmahos GC, Toutouzas K, Radin R, Chan L, Rhee P, Tillou A et al (2003) High success with nonoperative management of blunt hepatic trauma: the liver is a sturdy organ. Arch Surg 138(5):475–480, discussion 80–81
28. Velmahos GC, Toutouzas KG, Radin R, Chan L, Demetriades D (2003) Nonoperative treatment of blunt injury to solid abdominal organs: a prospective study. Arch Surg 138(8):844–851
29. Demetriades D, Gomez H, Chahwan S, Charalambides K, Velmahos G, Murray J et al (1999) Gunshot injuries to the liver: the role of selective nonoperative management. J Am Coll Surg 188(4):343–348
30. Demetriades D, Hadjizacharia P, Constantinou C, Brown C, Inaba K, Rhee P et al (2006) Selective nonoperative management of penetrating abdominal solid organ injuries. Ann Surg 244 (4):620–628
31. Omoshoro-Jones JA, Nicol AJ, Navsaria PH, Zellweger R, Krige JE, Kahn DH (2005) Selective non-operative management of liver gunshot injuries. Br J Surg 92(7):890–895
32. Beekley AC, Blackbourne LH, Sebesta JA, McMullin N, Mullenix PS, Holcomb JB (2008) Selective nonoperative management of penetrating torso injury from combat fragmentation wounds. J Trauma 64(2 Suppl):S108–S116, discussion S16–17
33. Carrillo EH, Platz A, Miller FB, Richardson JD, Polk HC Jr (1998) Non-operative management of blunt hepatic trauma. Br J Surg 85 (4):461–468
34. Karkiner A, Temir G, Utku M, Ucan B, Hosgor M, Karaca I (2005) The efficacy of non-operative management in childhood blunt hepatic trauma. Ulus Travma Derg 11(2):128–133
35. Sidhu MK, Hogan MJ, Shaw DW, Burdick T (2009) Interventional radiology for paediatric trauma. Pediatr Radiol 39(5):506–515
36. Velmahos GC, Demetriades D, Chahwan S, Gomez H, Hanks SE, Murray JA et al (1999) Angiographic embolization for arrest of bleeding after penetrating trauma to the abdomen. Am J Surg 178 (5):367–373
37. Hagiwara A, Yukioka T, Ohta S, Tokunaga T, Ohta S, Matsuda H et al (1997) Nonsurgical management of patients with blunt hepatic injury: efficacy of transcatheter arterial embolization. Am J Roentgenol 169(4):1151–1156
38. Gorich J, Rilinger N, Brado M, Huppert P, Vogel J, Siech M et al (1999) Non-operative management of arterial liver hemorrhages. Eur Radiol 9(1):85–88
39. Rubin BE, Katzen BT (1977) Selective hepatic artery embolization to control massive hepatic hemorrhage after trauma. Am J Roentgenol 129(2):253–256
40. Petroianu A (2007) Arterial embolization for hemorrhage caused by hepatic arterial injury. Digest Dis Sci 52(10):2478–2481
41. Tzeng WS, Wu RH, Chang JM, Lin CY, Koay LB, Uen YH et al (2005) Transcatheter arterial embolization for hemorrhage caused by injury of the hepatic artery. J Gastroenterol Hepatol 20 (7):1062–1068
42. Petroianu A (2005) Transcatheter arterial embolization for hemorrhage caused by injury of the hepatic artery. J Gastroenterol Hepatol 20(7):973–974
43. Kokudo N, Makuuchi M (2004) Current role of portal vein embolization/hepatic artery chemoembolization. Surg Clin North Am 84 (2):643–657
44. Burgmans MC, Irani FG, Chan WY, Teo TK, Kao YH, Goh AS, et al. (2012) Radioembolization after portal vein embolization in a patient with multifocal hepatocellular carcinoma. Cardiovasc Interv Radiol [Epub]
45. Ebata T, Yokoyama Y, Igami T, Sugawara G, Takahashi Y, Nagino M (2012) Portal vein embolization before extended hepatectomy for biliary cancer: current technique and review of 494 consecutive embolizations. Digest Surg 29(1):23–29
46. Siriwardana RC, Lo CM, Chan SC, Fan ST (2012) Role of portal vein embolization in hepatocellular carcinoma management and its effect on recurrence: a case–control study. World J Surg
47. Okabe K, Beppu T, Masuda T, Hayashi H, Okabe H, Komori H et al (2012) Portal vein embolization can prevent intrahepatic metastases to non-embolized liver. Hepatogastroenterology 59(114):538–541
48. Nesher E, Aizner A, Kashtan H, Kaplan O, Kluger Y, Greenberg R (2002) Portal vein air embolization after blunt abdominal trauma: a case report and review of the literature. Eur J Emerg Med 9 (2):163–165
49. Vauthey JN, Matthews CC (1988) Portal vein air embolization after blunt abdominal trauma. Am Surg 54(9):586–588
50. Jalan R, John TG, Redhead DN, Garden OJ, Simpson KJ, Finlayson ND et al (1995) A comparative study of emergency transjugular intrahepatic portosystemic stent-shunt and esophageal transection in

the management of uncontrolled variceal hemorrhage. Am J Gastroenterol 90(11):1932–1937
51. You LY, Li YC, Yan D, Xu Y, Yang J, Yang LH, et al. Clinical application of the transjugular intrahepatic portosystemic stent-shunt in the emergency treatment of esophagogastric varices bleeding due to cirrhosis. Zhonghua Gan Zang Bing Za Zhi 19(7):490–493
52. Dakkak AR, Welp H, Schmidt H, Koehler M, Scheld HH, Sindermann JR (2011) Treatment of chronic ascites due to right-sided heart failure by transjugular intrahepatic portosystemic shunt stent-implantation after orthotopic heart transplant. Experimental and clinical transplantation. Exp Clin Transplant 9(2):156–158
53. Ogura Y, Kanazawa H, Yoshizawa A, Nitta T, Ikeda T, Uemoto S (2011) Supradiaphragmatic approach for Budd-Chiari syndrome with transjugular intrahepatic portosystemic shunt stent in combination with inferior vena cava reconstruction during living donor liver transplantation: a case report. Transplant Proc 43(5):2093–2096
54. Therapondos G, Wong F (2006) Miscellaneous indications for transjugular intrahepatic portosystemic stent-shunt. Eur J Gastroenterol Hepatol 18(11):1161–1166
55. Tripathi D, Jalan R (2006) Transjugular intrahepatic portosystemic stent-shunt in the management of gastric and ectopic varices. Eur J Gastroenterol Hepatol 18(11):1155–1160
56. Tripathi D, Redhead D (2006) Transjugular intrahepatic portosystemic stent-shunt: technical factors and new developments. Eur J Gastroenterol Hepatol 18(11):1127–1133