4 Interventional Ultrasonography

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4.1 Introduction

Ultrasound guidance can be used to control percutaneous interventions [1]. With fine needles, tissue consistency can be explored, fluids from cysts or other cavities can be aspirated, and chemical agents can be injected for pharmacological therapy or to tattoo regions. Thin needles are used to aspirate cells for cytology, and larger-core biopsy needles can harvest tissue for histological examinations. Laser fibers and radiofrequency probes advanced through needles can coagulate vascular lesions, which can be monitored by ultrasonography. Catheterization of vessels for vascular access or of salivary ducts for drainage is possible. Salivary gland stones can be fragmented and extracted in a minimally invasive way using ultrasound control.

4.2 General Techniques

For the setup, it is advantageous if the patient is positioned between the ultrasound screen and the examiner (Fig. 4.1), so that the examiner can observe both the patient and screen without having to turn around. Depending on the intervention planned, it may be advisable to move the ultrasound machine or the position of the examiner. For example, for a sonographically controlled intervention involving the left parotid gland, the examiner would sit on the opposite (right) side, and the ultrasound screen would be placed on the left side of the patient.

Fig. 4.1 Setting for interventions under sonographic control in the office (**a**) and in the surgery room (**b**). The patient is located between the ultrasound screen and the examiner, allowing the examiner to control the procedure both on the screen and under direct vision without having to turn around

Two major approaches are commonly used to guide interventions with ultrasound: long axis (parallel) and short axis (perpendicular). In the long-axis technique, the long axis of

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the ultrasound transducer is placed parallel to the planned trajectory of the instrument (Fig. 4.2). The major advantage of this technique is that the needle or instrument can be monitored throughout its entire course toward the target. In the short-axis technique, the instrument is inserted to cross underneath the short axis of the transducer within the patient; the trajectory is perpendicular rather than parallel (Fig. 4.3). In this approach, the instrument is visualized only over a short distance as it passes immediately deep to the ultrasound beam, most often when it is within the target structure. It can be helpful to tilt the transducer very slightly to increase the monitored part of the trajectory. Benefits of this technique are that it also allows the simultaneous visualization of structures that are outside the plane of the target structure and the instrument trajectory. Additionally, sometimes the space on the surface is not sufficient to place the transducer parallel to the axis of the instrument (e.g., in the retromandibular space). Also, the distance the instrument must travel within the tissues is usually shorter than by the parallel approach.

Fig. 4.2 Long-axis technique: The planned trajectory of the instrument is within the plane of the ultrasound transducer; that is, they are parallel

Fig. 4.3 Short-axis technique: The planned trajectory of the instrument is not parallel to the plane of the ultrasound transducer; that is, it will cross this plane at only one point. This technique is often called "perpendicular," but in fact the trajectory is seldom perpendicular to the plane of the ultrasound transducer

The following order is suggested to perform the procedure:

- Visualize the target structure.
- Plan a trajectory avoiding sensitive structures.
- Align the ultrasound transducer and the instrument.
- Start with some distance to the transducer (otherwise, the instrument may not be deep enough or the angle of insertion may be difficult).
- Correct the ultrasound transducer position by very slight adjustments to visualize the target and instrument at the same time. (Avoid gross movements.)
- Visualization of the tip of the instrument is most important to avoid collateral damage and to confirm biopsy or therapy in the correct location.
- If it is not possible to reach the target with the instrument, pull it back. Do not bend the instrument.

The following paragraphs present different applications. This list is not complete, as overlaps, modifications, and additional nonlisted options exist.

4.3 Indications

4.3.1 Punctures

Punctures (or percutaneous insertions) are usually performed using sharp needles penetrating the tissue. Punctures with fine needles or small diameters often do not require local anesthesia. For larger diameters, at least anesthesia of the skin is recommended. Sometimes it even may be advisable to incise the skin with a scalpel before introduction of the puncture device. Local anesthesia too close to the target increases the risk of bloody biopsy specimens. In certain cases with acute infections (such as a deep neck abscess in a child), local anesthesia may not be effective because of the altered pH of the tissues, so that general anesthesia becomes necessary.

Testing of Tissue Consistency

High contrast of acoustical impedance between tissues can result in total reflections. Typically, this can be seen on the surface of calcifications or air-filled structures. Calcifications can be solid stones or accumulations of small calcified structures in the tissue, such as lymph nodes with tuberculosis. The differentiation of these structures using ultrasound can be difficult. Sometimes stones or air can be moved by applying pressure from the outside, either with the transducer or by palpation (e.g., a finger inside the mouth). The additional use of a needle can add essential information, as air can be aspirated, and solid stones offer resistance to the needle and will be moved visibly (Video 4.1). Small calcifications or soft stones will easily be penetrated by the needle, so that no relevant movement of the structure in relation to the surrounding tissue will result. After identification of a parotid stone by this technique, the needle can also be used to guide a surgeon toward the stone for extraction during open surgery [2].

Aspiration of Liquids and/or Instillation of Therapeutic Liquids or Liquids for Marking Structures

The lumen of the needle can be used both to aspirate and to inject liquids. Aspiration can be used to drain liquid-filled cavities like infected cysts, sialoceles, abscesses, and hematomas (Video 4.2). Fluid for microbial culture can be obtained at the same time. Therapeutic liquids like 96–98% alcohol, picibanil (OKT432), or doxycycline can be injected to sclerose thyroid cysts, lymphoepithelial cysts of the parotid gland, or vascular lesions like lymphatic malformations [3]. The procedure typically involves first aspiration to empty the lesion, followed by injection of the sclerosing agent.

It is important to note that nerve damage (e.g., vocal fold paralysis or facial paralysis, depending on the site of the lesion) can occur [4]. It has been recognized that seepage of the sclerosing agent or nerve compression by a sudden increase in the tissue pressure around the lesion might cause adjacent nerve injury.

In addition to ultrasound guidance for injecting liquid-filled lesions, additional indications include injections into parenchyma, such as the salivary glands, typically in a diffuse (fanlike) manner. An important drug for these injections is botulinum toxin. Botulinum toxin is a bacterial neurotoxic protein that inhibits the release of acetylcholine from axon endings. Type A of this toxin is used for a variety of indications, including muscular hyperactivity (e.g., blepharospasm or cervical dystonia) or to decrease secretion from glands (e.g., hyperhidrosis or hypersalivation) [5–8]. The use of ultrasound can be helpful to ensure that the toxin is delivered near to the relevant axon endings. If the patient has become refractory to botulinum toxin type A, a possible alternative is botulinum toxin type B.

The spectrum of therapeutic options in the head and neck region includes several uses:

- Injection of botulinum toxin into the salivary glands for sialorrhea (Video 4.3) (25 G–27 G needle, total of 100–400 IU per session, distributed onto the large salivary glands. For children, e.g., 30 IE into each parotid and 20 IE into each submandibular gland). Repetition might be necessary after 2–4 months. Recent publications have shown that the use of botulinum toxin for this indication is safe even in the pediatric population [9–11]. Side effects include swallowing disorders, which are usually temporary [12, 13].
- Injection of botulinum toxin into sialoceles or into the gland parenchyma for salivary fistulas after open gland surgery (30–100 IU per gland or lesion, diluted in about 10 mL of saline) [14–16].
- Injection of botulinum toxin into the area of maximum pain for first bite syndrome, occasionally occurring after parapharyngeal space surgery [12, 13]. This procedure often causes very brief but intense pain for the first 5–10 seconds after injection. Therefore, it can be helpful to use an ice pack or ice spray before and after the procedure.
- In contrast to these techniques, the injection of botulinum toxin into the skin for Frey's syndrome after parotidectomy (0.1 IU/cm^2) is usually done without ultrasound control [17–19].

Lesions such as lymph nodes can be marked by dyes before extirpation to facilitate intraoperative identification and ensure retrieval of the intended target [20, 21]. The volumes of dye used are small (up to 0.2 mL), as too much can result in a diffuse staining of a large tissue area. Activated charcoal can be injected even 3 weeks before the procedure, whereas methylene blue is usually injected immediately preoperatively. Intraoperative identification can also be achieved by ultrasound-guided needle localization. The principle is described in detail above, as it can also be used to test for tissue consistency. Foreign bodies in soft tissue (such as wood, plastic, or metal) can be visualized sonographically and marked with a needle before instruments like hemostats are introduced through wound channels to remove the objects or before open surgery is performed for removal [22, 23].

Cytologic Examinations (Fine Needle Aspiration)

Ultrasound-guided fine needle biopsies provide aspirate samples for cytologic, immunocytochemical, and chemical diagnosis (Fig. 4.4) [24–26]. It is important to ensure for fine needle aspiration (FNA) cytology that the needle tip is within the target lesion, to ensure that the cells examined are from the area of interest. Larger needle sizes may gain larger tissue samples but also increase the risk of cell seeding, bleeding, and discomfort for patients. Preferred needle diameters range between 23 G and 27 G, with larger diameters (up to 14 G) used for core biopsies. There is debate about the optimal number of needle passes, which is influenced by many factors, including operator experience, tissue source, technique, and ability to perform on-site microscopic assessment of adequacy. Negative pressure or suction can increase the sample size but also increases the risk of collecting blood, which may hinder the cytologic

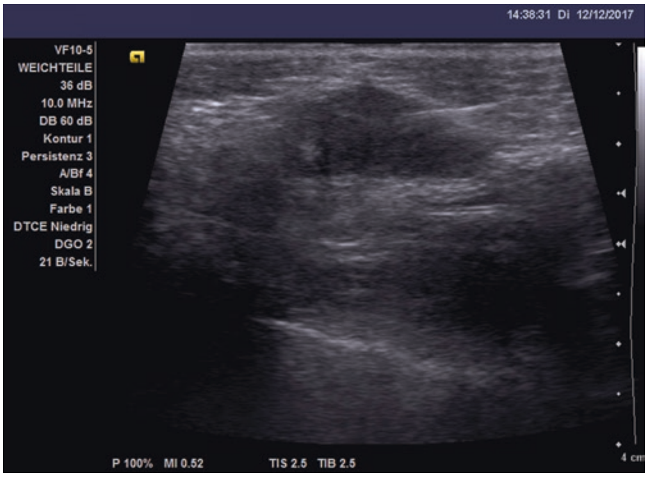

Fig. 4.4 Fine needle aspiration (FNA) cytology under sonographic control in the patient from the figures above. The needle tip can be seen inside the lesion of the anterior parotid gland. In this case, an adenoid cystic carcinoma was diagnosed by cytology

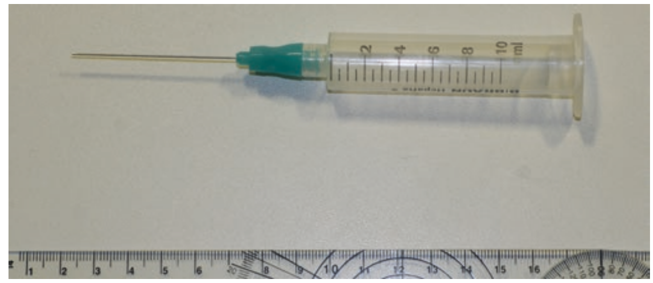

Fig. 4.5 Set for performing FNA with the capillary technique: the plunger of the syringe has been removed. The tissue sample is obtained without any suction, but the plunger can be reinserted to harvest the cells from inside the injection needle

Fig. 4.6 A handle can facilitate FNA using the suction technique (device from Cameco AB, Täby, Sweden)

interpretation. Without suction, only capillary forces and the pressure of the needle perforating the tissue will collect the sample (Fig. 4.5). Suction is usually achieved via a syringe. Specially designed handles facilitate one-handed use (Fig. 4.6). If an assistant is available, the needle might be connected to the syringe by extension tubing. Alternatively, a stopcock between the needle and tube allows the syringe to be “pre-loaded” for one-person use.

Before obtaining the specimen, the preferred method of preparing the sample should be discussed with the pathologist. Some pathologists prefer that a smear be performed on glass slides, while others prefer rinsing the cells for liquid-based processing. The preferred liquid and fixative should also be discussed. The needle also can be rinsed with saline after expelling the specimen, with the needle washout submitted for chemical testing (such as for thyroglobulin or parathyroid hormone).

Histologic Examinations (Core Biopsy)

The diameters of devices for core biopsy (CB) are typically larger than for FNA cytology [25, 26]. Additionally, they usually include a mechanism to cut out a cylindrical specimen from the tissue. Figure 4.7 shows different devices. It is important to note that in some devices the total advancement of the needle is controlled manually (Video 4.4). In other devices, however, the operator must aim and then release the needle, which then advances rapidly by a spring mechanism (Video 4.5). These devices require special caution, as miscalculation of the advancing distance, wrong settings of the device, or movements of the patient can lead to painful or even dangerous complications. One of the authors once hit the vertebral column of a patient, fortunately without adverse results, but we are aware of one tragic, unpublished case from a regional colleague in which the core biopsy included parts of the carotid artery, resulting in a lethal outcome.

The specimen obtained is usually processed like any other histologic sample by being placed in formalin. However, pathologists might ask that tissue for lymphoma studies should be submitted fresh, in saline or tissue support medium.

4.3.2 Destruction of Tissues

Laser therapy of vascular lesions such as venous malformations can be performed percutaneously with ultrasound guidance [27]. However, when using a Nd:YAG laser, the maximum depth of the coagulative effect is about 1 cm. To reach deeper parts of a lesion or to spare the superficial tissue, interstitial therapy is delivered via a cannula that is introduced into the lesion and advanced as far as the coagulation is planned. Larger vessels or high-flow areas should be avoided, as laser coagulation might not achieve sufficient coagulation of these areas. The bare fiber is introduced through the lumen of the steel needle. The tip of the bare fiber can be seen on ultrasound (Fig. 4.8, Video 4.6). However, it is advantageous to mark the bare fiber (e.g., with a Band-Aid or other stop) at the distance to which it

Fig. 4.7 A multitude of devices can be used to obtain core bore biopsies. (**a**) A selection of devices (from left to right, without preference): Chiba Biopsy Needle, 23 G × 5 cm, with "echotip" (a roughened surface near the tip for better echogenicity), Cook Inc., Bloomington, IN, USA; Quick-Core Biopsy Needle, 20 G × 15 cm, Cook Inc., Bloomington, IN, USA; Temno Biopsy System, 20 G × 6 cm, Carefusion/Becton Dickinson, Franklin Lakes, NJ, USA; Magnum Biopsy System, C.R. Bard Inc., Murray Hill, NJ, USA; BioPince, Full Core Biopsy Instrument, 18 G × 10 cm, Argon Medical Devices Inc., Athens, TX, USA; Tru-Cut biopsy device, 18 G × 24 cm, Angiomed, Becton Dickinson, Franklin Lakes, NJ, USA; Spirotome, Soft Tissue Biopsy Needle Set, outer needle (right side around the trocar): 8 G × 15 cm; inner needle with spiral cutting tip (left side): 10 G × 22 cm, Cook Inc., Bloomington, IN, USA; Biopsie Handy, 18 G × 10 cm, Somatex Medical Technologies GmbH, Teltow, Germany. (**b**) Tips of the devices shown. (**c**) Using the Spirotome: outside view. (**d**) Using the Spirotome: sonographic view. Optional port systems (e.g., coaxial introducer systems) are available that allow multiple tissue samples to be obtained through a single insertion site

should be introduced into the cannula, so that either retraction into the plastic cannula or too much protrusion can be avoided. Retraction can result in the coagulation of plastic, and protrusion can result in a broken fiber. After making sure that the fiber is introduced well and aims at the target tissue, coagulation is started. (The Nd:YAG laser can be set to 5–20 W, but the tissue response should be observed.) The tissue usually responds with increasing echogenicity. Both the fiber and the outer plastic cannula are retracted simultaneously, observing the effect on the tissue. In this way, a cylindrical coagulation zone is created. It can be helpful to stop the laser only after total removal of the fiber and cannula, as otherwise bleeding from the puncture site may result.

4.4 Catheterization

4.4.1 Treatment of Stenotic Salivary Ducts

Obstructive sialadenitis is caused either by sialolithiasis (discussed below) or by ductal stenosis. Ultrasound can allow assessment of the length of the stenosis without having to pass through it. Often the duct is dilated proximal to the stenosis because of the blockage of the saliva flow. This dilatation of the proximal part can be increased using a sialagogue, while the distal part can be dilated by flushing the duct from its distal opening with saline, using a plastic IV cannula. Under sonographic control, metal or plastic dilators or balloons can be used to increase the

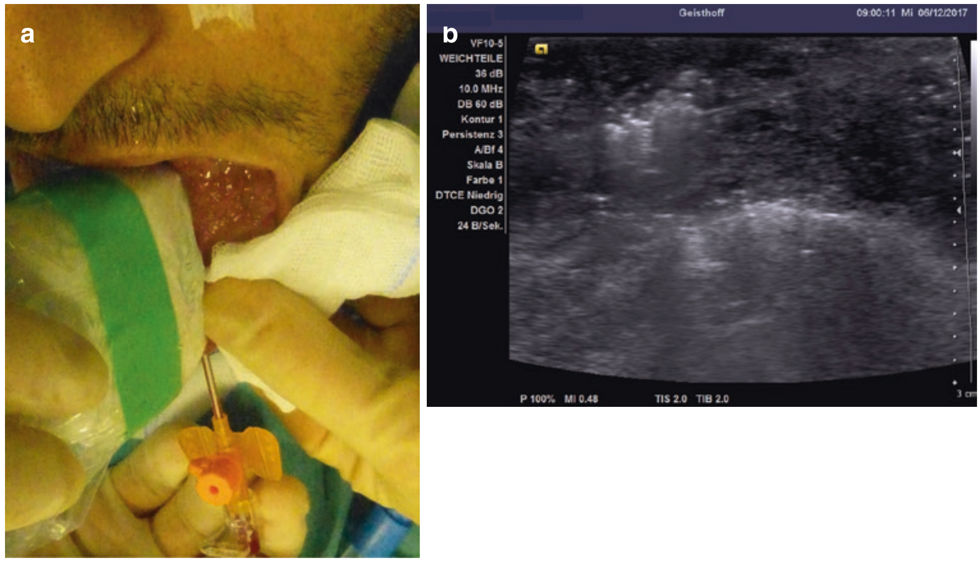

Fig. 4.8 (**a**) A cannula is introduced into a venous malformation of the tongue under sonographic control. In the middle of the steel needle lies a bare fiber, which is advanced to coagulate the tissue. (**b**) The coagulation effect can be monitored by ultrasound

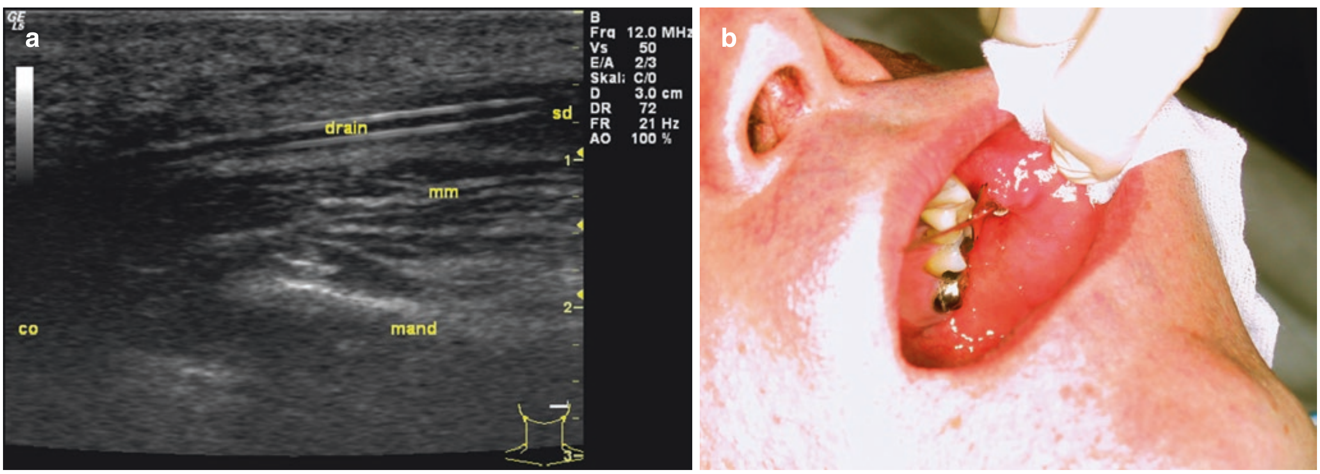

Fig. 4.9 (**a**) A drain has been placed into a stenotic left Stensen's duct under sonographic control. (From Jecker et al. [29], with permission.) (**b**) The probe that has been used for positioning the drain is still inside the drain. co oral cavity (cavitas oris), mand mandible, mm masseter muscle, sd Stensen's duct

diameter of the duct [28, 29]. The effect of the dilation process can be well seen by ultrasound. Plastic or metal dilators can be placed from distal to the stenosis by sonographic control. However, the process of dilation is usually difficult to visualize, as the dilators not only widen the duct but also move it parallel or sideward to the ultrasound transducer (Video 4.7).

Stents or drains can be used to keep the lumen of the dilated duct open (Fig. 4.9). However, this is not universally recommended. Some authors favor only irrigation of the fresh wound with corticosteroids. Stents can be placed under sonographic control (*see* Video 4.7).

4.4.2 Vascular Access/Cannulas

Ultrasound-guided vascular access, which is increasingly used by anesthesiologists and hospitalists, can also be used by head and neck surgeons [30]. After identification of the target vessel, the catheter is usually introduced by either the short-axis or long-axis technique (Video 4.8). It is important to remember that the venous pressure in the area of interest must be sufficient, which can be achieved by placing the region of interest in a dependent position, by the Valsalva maneuver, or by asking the anesthesiologist to increase the PEEP (positive end-expiratory pressure).

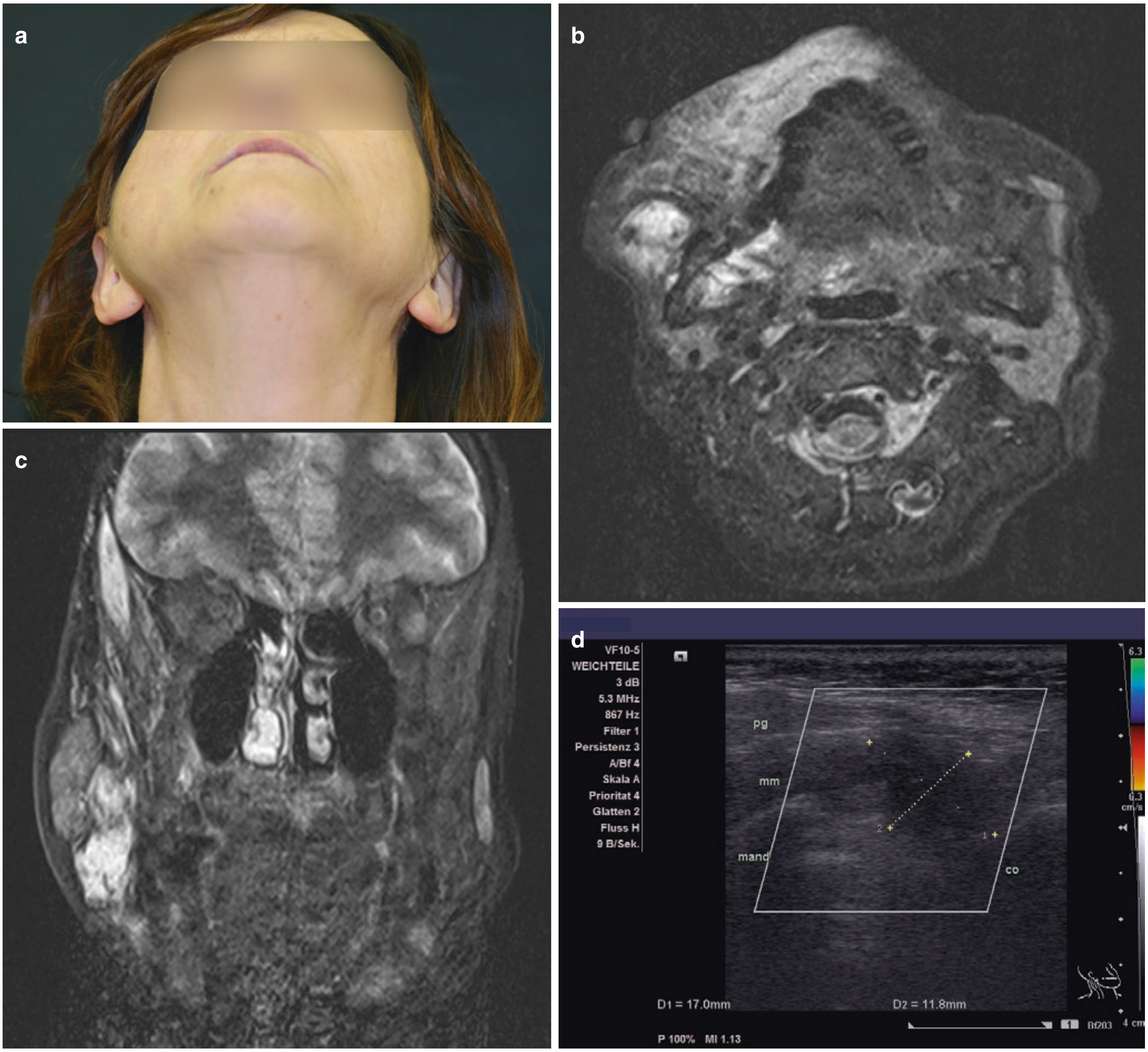

Fig. 4.10 (**a**) Outer aspect of a venous malformation of the right cheek. The intermittent swelling led to recurrent asymmetry and discomfort. (**b, c**) Axial and coronal MRI views of this venous malformation (Courtesy of Prof. Dr. Bien and Dr. Gurschi, Neuroradiology, Univ. of Marburg). (**d**) Sonographic view of the same venous malformation. Sometimes the flow is very low and can barely be detected by duplex sonography. In this case, slight compression of the lesion can induce a visible flow, as in Video 4.9a

A special form of vascular access is the catheterization of a vascular anomaly for radiologically controlled sclerosis, a technique that overlaps with the instillation of therapeutic liquids as discussed above. In this case, the lesion is only identified and punctured under sonographic control. After establishing the access, the sclerosing procedure is performed under sonographic control. Figure 4.10 shows the outer and imaging aspects of a venous malformation before therapy. Video 4.9 demonstrates the flow inside the lesion and the needle inside it. Figure 4.11 shows the angiographic aspect of the lesion after injection of contrast material and Histoacryl glue.

Ultrasound also can be used to select the more suitable side for implantation of a port into the cephalic vein.

4.5 Treatment of Sialolithiasis

4.5.1 Mobilization of the Stone for Drainage

Stones can be mobilized either using the finger (Video 4.10) or by inserting a probe into the duct (Video 4.11), allowing blocked saliva or pus to be excreted. The effect is often only of short

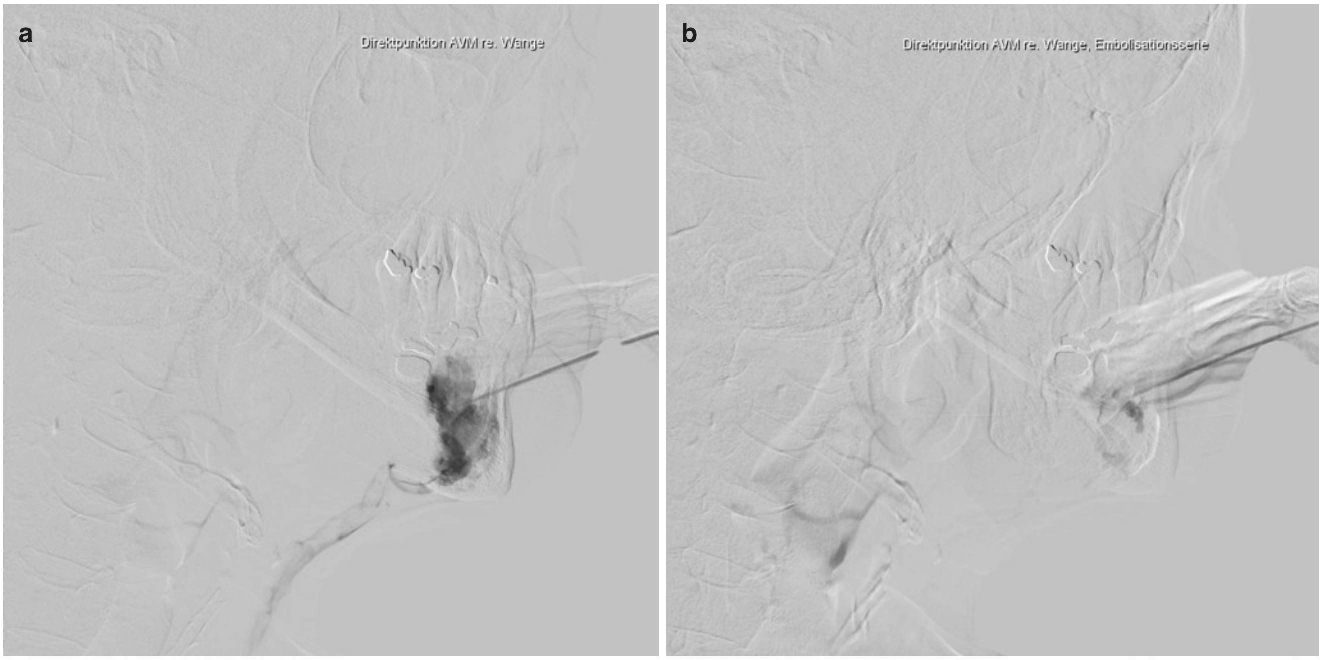

Fig. 4.11 Angiography performed after direct puncture of the venous malformation shown in Fig. 4.10 and Video 4.9, with injection of contrast material (**a**) and Histoacryl glue mixed with contrast material for sclerosis (**b**). (Courtesy of Prof. Dr. Bien and Dr. Gurschi, Neuroradiology, Univ. of Marburg)

duration, as the flow of the secretion will return most stones to the same position, but sometimes a different position is achieved, which leaves enough space next to the stone for secretion.

4.5.2 Extraction of the Stones (Basket or Forceps)

Not only probes but also other instruments can be introduced into the duct through the natural papilla. In addition to ultrasound control, other methods of guidance can be used, including sialendoscopy, haptics, or x-ray (with the disadvantage of radiation exposure) [29]. Haptics are often only sufficient if the pathology is very near to the papilla. Sialendoscopy is often an excellent measure, but it requires special instrumentation and experience. Additionally, part of the duct lumen is occupied by the endoscope, which can prevent the use of larger instruments. It can be helpful to combine different methods (multimodal therapy) to increase the success rate [31].

Both baskets (Fig. 4.12) and miniforceps (such as those used for ear surgery) (Figs. 4.13, 4.14, and 4.15) can be introduced into the lumen of Stensen's or Wharton's duct. This frequently first requires the dilation of the papilla. Afterward, the instrument is directed toward the stone. Reaching the stone can be difficult or even impossible if the duct is tortuous, stenotic, or bifurcated distal to the stone. When the stone is reached, the instrument jaws or wires are opened, and the stone is grasped and extracted (Video 4.12). Extraction is possible only if the duct diameter allows it, however. If in doubt, instruments such as forceps or half-open baskets should be used, which can release the stone in case of blockage. Sometimes, a mini-papillotomy is necessary to overcome the papilla.

4.5.3 Fragmentation of Stones

If the diameter of the stone is too large in relationship to the duct, either the duct has to be dilated, or the stone must be broken into smaller pieces by methods such as extracorporeal shock wave lithotripsy (ESWL) or intraductal pneumatic or laser lithotripsy under sialendoscopic control. Fragmentation by forceps under sialendoscopic control is also possible, but because these forceps are often very small, they can crush only soft stones. Forceps for middle ear surgery, of different diameters and shapes, usually allow application of sufficient force and can be controlled by ultrasound [32, 33]. The fragmentation of the stone can often be felt, heard, and seen on the ultrasound screen (Fig. 4.14, Video 4.13). Often multiple crushing closures of the jaws are necessary. Afterward, the fragments are removed as described above (Fig. 4.15).

ESWL for salivary gland stones is also performed under sonographic control. Figures 4.16 and 4.17 show the setting of ESWL, and Video 4.14 shows the picture on the ultrasound screen during the procedure.

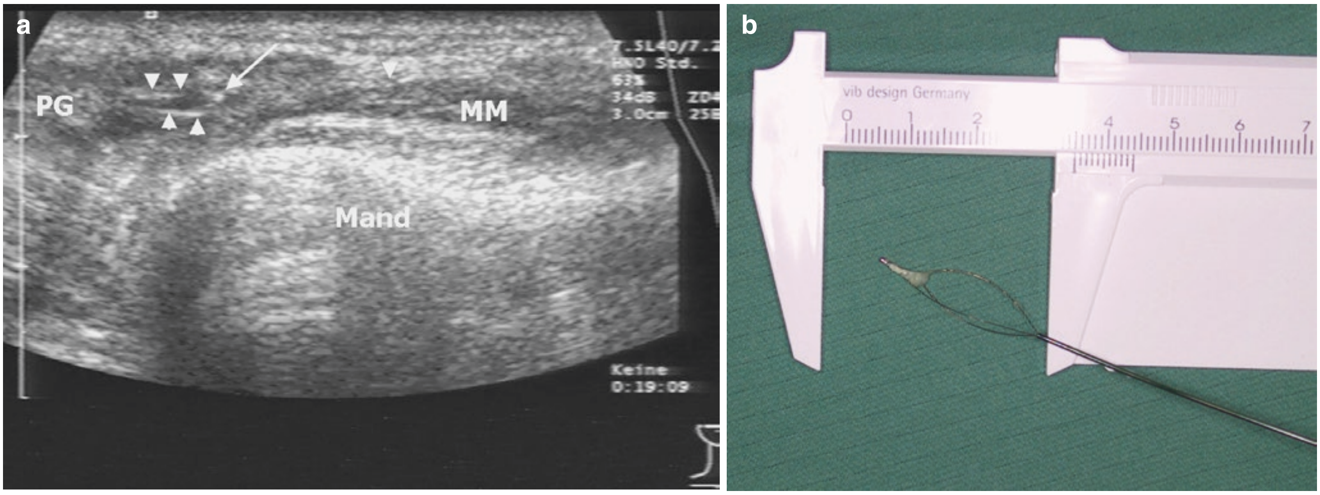

Fig. 4.12 (**a**) A small stone (*arrow*) inside the right Stensen's duct (*single arrowhead*) is grasped by a Dormia basket (*four arrowheads*). Mand mandible, MM masseter muscle, PG parotid gland. (**b**) A small stone has been extracted by a Dormia basket

Fig. 4.13 A small forceps has been introduced into the right Stensen's duct and is now monitored by ultrasonography

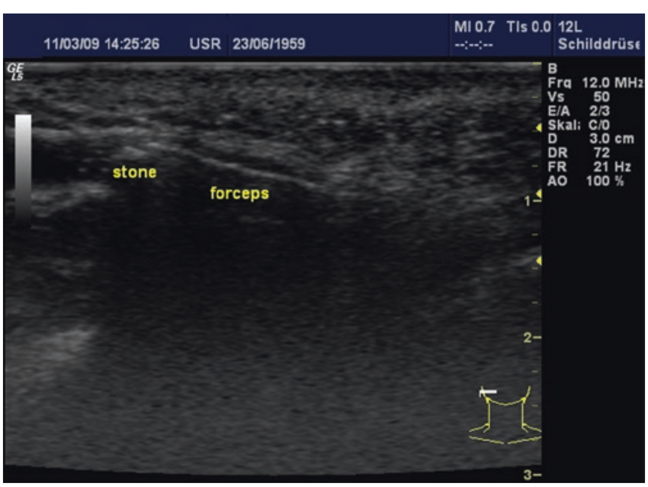

Fig. 4.14 Forceps introduced in right Stensen's duct and grasping a stone. (From Jecker et al. [29], with permission)

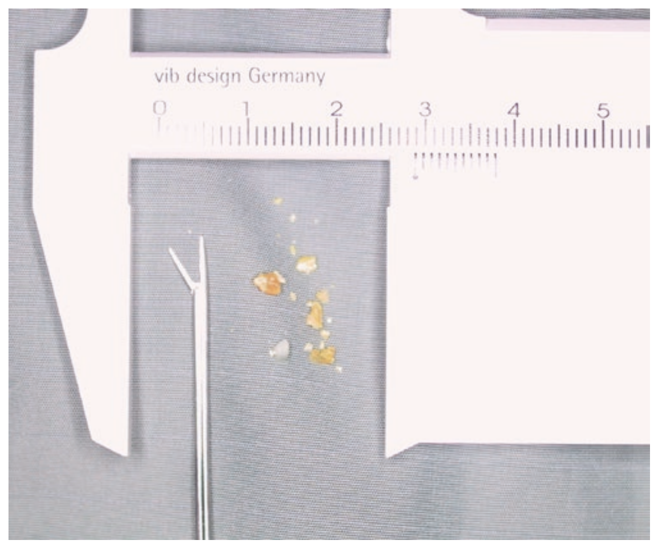

Fig. 4.15 A miniforceps and a salivary gland stone that was fragmented under sonographic control

4.6 Technical Remarks

Industry offers quite a variety of devices that can be used for ultrasound-guided procedures. Echogenicity of the tip of instruments can sometimes be improved by turning the tapered section of the needle tip toward the ultrasound transducer, as this leads to an additional reflection plane. A further increase of echogenicity is produced by the roughening of the polished metal surfaces near the needle tip (*see* Fig. 4.7). As the price is higher than that of normal needles, such needles are used only for more complex circumstances, such as for treatment of handicapped children under local anesthesia.

Fig. 4.16 Extracorporeal shock wave lithotripsy (ESWL) using the Minilith system (Storz Medical, Switzerland). The treatment cushion containing the ultrasound head and the electromagnetic shock wave generator are positioned over the stone

Fig. 4.17 The ultrasound screen of the ESWL machine shows cross-hairs in which the stone must be positioned

Attachable needle guides available for some transducers correspond to diagonal lines projected onto the image on the screen. However, they limit flexibility in biopsy direction. Additionally, they can never compensate for a bend of the needle. Such guides are rarely necessary once experience with ultrasound guidance has been obtained.

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