Chapter 10
Subdural Hematomas in Adults and Children

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10.1 Introduction

Subdural hematoma (SDH) is one of the most common phenomena a neurosurgeon encounters. Since ancient times, trephination has been performed to relieve the sick of their symptoms. While craniotomy is still the modality of choice for SDH, the search for a better solution is a never-ending endeavor. Acute (aSDH) and chronic (cSDH) forms of the hematoma have different pathophysiology; hence, different treatment approaches are required. Craniotomy or craniectomy may be the required intervention for aSDH. For cSDH, twist-drill craniostomy (TDC), burr-hole craniostomy (BHC), and middle meningeal artery (MMA) embolization are various medical treatment options developed and researched to better manage the disease and reduce the cost of medical expenses. Here we present current treatment options for SDH.

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C. Di Rocco (ed.), *Advances and Technical Standards in Neurosurgery*, Advances and Technical Standards in Neurosurgery 46, https://doi.org/10.1007/978-3-031-28202-7_10

10.2 Surgical Management of Subdural Hematoma in Adult Population

An aSDH develops after a traumatic brain injury with an incidence of 31% [1]. About 69.8–74.3% of these patients are initially treated conservatively [1, 2]. Of these patients, 6.5–11% required delayed surgery primarily due to the progression of the aSDH, and raised intracranial pressure (ICP) [1, 2]. While the decision for surgery remains controversial and varies from one center to another, Brain Trauma Foundation guidelines are still used today [1]. The guideline states that an aSDH thickness >10 mm or >5 mm midline shift should be surgically evacuated regardless of GCS score. A patient with GCS <9 without the abovementioned criteria should be evaluated for surgery if the GCS score drops by 2 or more points during hospitalization or if there is an asymmetric dilated pupil or ICP of >20 mmHg [3].

A cSDH is usually a disease of the elderly with an incidence of 1.72–20.6 per 100,000 which increases with age [4, 5]. There is consensus that large hematoma size, midline shift of more than 5 mm (Fig. 10.1), the disappearance of the basal cisterns, and a neurologic deficit are indications for surgery [6]. Contrary to aSDH, cSDH is a process that develops over time and may be silent for some time before the onset of the symptoms [4].

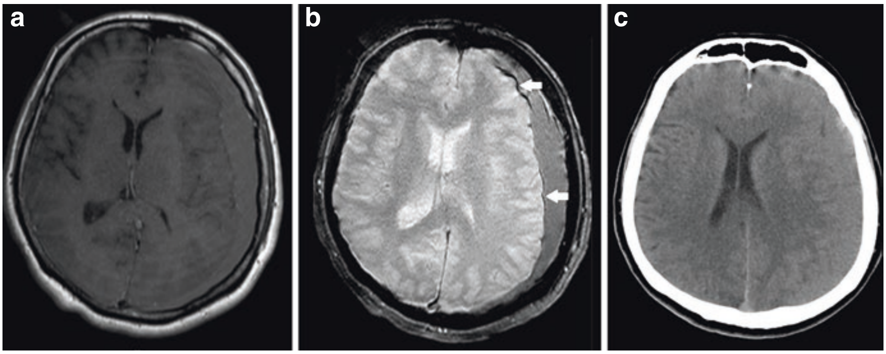

Fig. 10.1 T1-weighted (**a**), T2*-GRE (**b**), and CT (**c**) images of a homogenous iso-dense cSDH with acute components on the frontal pole of the hematoma. Large hematoma volume and midline shift support surgical intervention. Hemosiderin staining is shown along the inner membrane of cSDH on T2*-GRE (white arrows)

10.2.1 Craniotomy, Minicraniotomy, and Endoscope-Assisted Surgery

A craniotomy is the main surgical treatment for aSDH. Surgery is useful for thick clot removal, possibly localizing and managing the source of the bleed and, if necessary, converting to craniectomy to relieve potential raised ICP, since most of the aSDH are a result of trauma. Bleeding is due to ruptured bridging veins or cortical arteries [7]. The craniotomy must encompass the acute hematoma borders as much as possible. The surgeon should avoid the superior sagittal sinus, and expose inferiorly to near the base of the temporal fossa including the greater wing of the sphenoid bone. A large 12 × 15 cm frontotemporoparietal craniectomy is recommended for severe traumatic brain injury [8]. The dura is incised in a starlike fashion. The hematoma is removed using a combination of suction, irrigation, and forceps with careful traction. Irrigation is a powerful tool for hematoma removal. After hematoma evacuation, careful inspection of the surface of the brain may reveal the bleeding origin. Bleeding is controlled with bipolar electrocautery or, preferably, with an absorbable hemostatic agent. A subdural soft drain may be placed if the irrigation fluid is not clear and the origin of the bleeding site cannot be visualized. The dura is sutured closed in a watertight fashion, and dural tenting sutures are placed circumferentially to prevent developing an epidural hematoma. The bone flap is replaced with plates and screws. Subgaleal drain placement and standard closure techniques are followed.

Minicraniotomy with endoscope-assisted surgery is another recent technique developed for treating the elderly since conventional surgery for both aSDH and cSDH can have an unfavorable outcome [9]. The rationale for this approach is the removal of the hematoma and identifying the source of the bleeding under local anesthesia in a patient with a high risk for general anesthesia or a major surgical intervention.

The standard craniotomy procedure is performed over the thickest part of the hematoma, with a 2–5 cm diameter craniotomy. A recent cadaveric study on craniotomy locations of the minicraniotomy for the endoscopic operations found a 3-cm-diameter craniotomy over the most convex point of the parietal bone between the superior temporal line and the mid-pupillary line provides for optimal reach with a rigid endoscope. Yet the authors state that a minimum of a 6 mm subdural space is needed to avoid cortical damage [10]. A flexible endoscope may provide a better view compared to a rigid endoscope, but this has little meaning if the other tools cannot reach to evacuate the hematoma [9]. The dura is incised in a starlike fashion, and hematoma removal using suction, irrigation, and forceps is ensued. Then, the endoscope is used to visualize and remove as much as possible of the rest of the hematoma with the same techniques. The source of the bleed is controlled with bipolar electrocautery if possible. Endoscope-assisted aSDH removal is an alternative technique that may be beneficial in select patients [9].

Craniotomy or endoscope-assisted minicraniotomy is reserved for patients with extensive membrane formations, calcified hematomas (Fig. 10.2), or recurrent

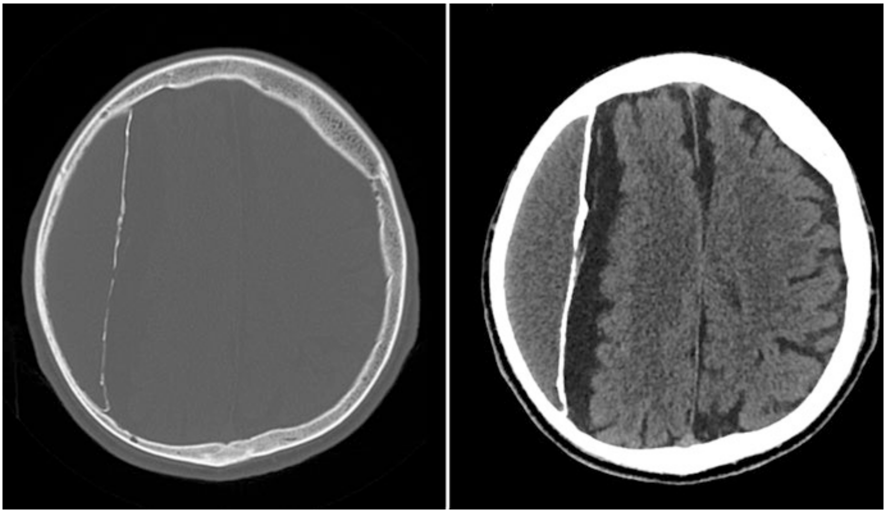

Fig. 10.2 CT image of a calcified/ossified cSDH, which requires craniotomy if the patient is symptomatic

bleeding [6, 11, 12]. Some studies report increased mortality or poor outcome for older patients with surgery [11, 13, 14]. Hence, the inclination toward minimal intervention has resulted in the development of safe and alternative techniques for cSDH treatment.

10.2.2 Burr-Hole and Twist-Drill Craniostomies

A burr-hole is described as a 10–30 mm craniostomy of the skull [15]. The hole must be drilled over the thickest part of the hematoma, typically in the parietal bone, slightly above the superior temporal line. A second burr-hole is preferable for large hematomas, usually in the frontal bone. The patient must be positioned so the frontal hole should be the highest point of the head. After the holes are prepared, bony bleeding must be waxed, and the dura is coagulated with bipolar cautery. In large hematomas and typically patients with a high Markwalder Grading Score (MGS), intracranial pressure (ICP) may be so high that a liquid hematoma may expel itself. The surgeon must avoid a sudden pressure drop and rapid expansion of the brain to avoid axonal injury. The dura and outer membranes are incised starting from the frontal hole; dark purple-red hematoma and the typical "engine oil" appearing fluid are evacuated. Irrigation of the hematoma with a soft catheter may be beneficial due to lower recurrence rates, without significant evidence [16]. Thorough irrigation is preferred without intradural cannulation in our center due to the reduced risk of the drain clogging with a clot and increased risk of parenchymal injury from blind insertion of the catheter. External membrane and dural leaflets are cauterized to avoid recurrence. The parietal hole is closed first with a mesh or gel foam, and the galea and skin are sutured. The subdural space is filled with saline, and a subdural or subgaleal drain is placed before the galea and skin closure. Drainage after hematoma evacuation is recommended and reduces the recurrence of cSDH by 60% [6, 16]. A subperiosteal drain is as effective as a subdural drain and has a potentially lower complication rate [6]. The order of closure of the holes and their filling with saline is meant to reduce air entrapment which may prevent brain re-expansion.

Twist-drill craniostomy is described as a quick and bedside intervention performed under local anesthesia. Under local anesthesia, approximately a 1 cm incision over the thickest part of the hematoma and drilling of the bone with a 45° angle to the surface of the bone are performed. The dura and the outer membrane are perforated, and the subdural cannula is inserted, which is connected to a reservoir for passive drainage [17]. Later modifications of the technique abandon intradural cannulation and instead place a hollow screw, YL-1 needle, or a subdural evacuating port system (SEPS) through the hole. This approach lowered the complication rates of the procedure and was deemed successful as first-line treatment as it is minimally invasive, requires no general anesthesia, and does not require occupying the operating room. TDC has a similar success and recurrence rate as BHC, with approximately half the complication rate of BHC [18].

Both BHC and TDC are effective in CSDH evacuation. The advantages of BHC are direct visualization and possible intervention of multiple membranes of the hematomas with subacute components or septations, which may occlude the TDC drain and result in unsuccessful hematoma resorption. Some studies report BHC to have a lower recurrence rate, yet some have found no significant difference [6, 19]. TDC on the other hand is easy to perform, suitable for patients with a high risk for general anesthesia and those with shorter hospitalization time [18, 20].

10.3 Embolization of Middle Meningeal Artery for Chronic Subdural Hematoma

It is hypothesized that the external membrane of cSDH is the reason for maintaining and expansion of the hematoma [21]. Recent studies propose eliminating the arterial supply of the tissue by embolizing MMA which might halt hematoma expansion and facilitate resolution [21]. MMA embolization significantly reduces the recurrence of cSDH compared to serial neuroimaging or surgical intervention [22].

Under local anesthesia, after femoral or radial arterial catheterization, a catheter is placed in the proximal external carotid artery. Selective angiography reveals the internal maxillary artery and MMA. A microcatheter is advanced into the MMA with a guidewire. Anastomoses of MMA branches with the ophthalmic artery and inferolateral trunk and anatomical variations of the artery must be kept in mind before the administration of the embolizing agent [23]. Branches supplying the dura are selectively cannulated and embolized with liquid or particle embolic agents (Fig. 10.3).

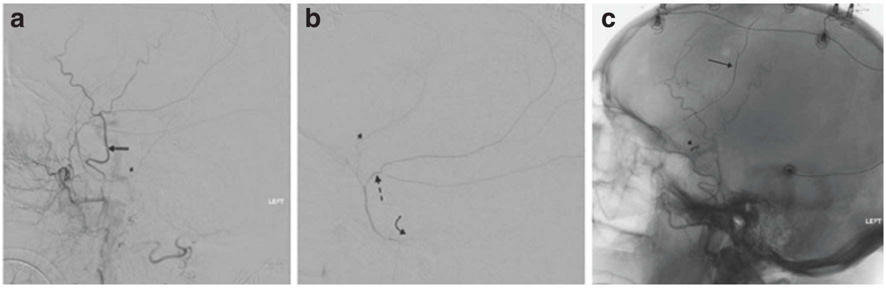

Fig. 10.3 Angiography demonstrating terminal branches of the left external carotid artery (**a**). MMA (asterisk) and superficial temporal artery (black arrow) are shown. Superselective angiography demonstrates the frontal (asterisk), parietal (dotted arrow), and petrosal branch (curved arrow) of MMA (**b**). The occluded frontal branch of MMA with a liquid embolic agent (arrow) and coil embolization of the parietal branch (asterisk) (**c**) [24]

While the technique is reserved for asymptomatic patients, since neurologic deterioration requires surgical intervention, MMA embolization is a promising treatment option. Several studies have found MMA embolization significantly reduces the recurrence rates of BHC and may be a viable first-line intervention for patients with asymptomatic cSDH and several medical comorbidities [6, 21, 22].

10.4 Medical Management of Chronic Subdural Hematoma

While surgical intervention is the primary approach to cSHD, in some patients surgery might not be a viable option due to comorbidities such as severe cardiac or pulmonary diseases. Surgical mortality and morbidity of patients with cSDH, which are typically in the elderly population, also support the initiative for nonsurgical treatment options. Patients with high surgical risk, with minor symptoms, and with an MGS score of 0–1 and those that refuse surgery are candidates for medical treatment [6]. Regardless of whether surgery is performed or not, recent studies recommend medical treatment to reduce recurrence [25]. Several medical alternatives have been established for the treatment of CSDH.

10.4.1 Dexamethasone

Neomembrane formation and leakage of blood or blood products from the neocapillaries of the membrane are the prominent theories for cSDH formation and maintenance [26]. Dexamethasone (DXM) may be beneficial in the resolution of hematoma by inhibition of the immune response ergo and maturation of neomembrane [27, 28]. A recent meta-analysis states that DXM is the best medication to prevent the recurrence of cSDH [25]. However, an overall increase in mortality with DXM even with low doses might negate the potential benefits [28]. Recent studies recommend the use of DEX in low doses and for short duration [25, 28].

10.4.2 Atorvastatin

Atorvastatin (ATO), an inhibitor of 3-hydroxy-3-methylglutaryl-coenzyme A reductase, has recently been established to reduce hematoma volume in cSDH through anti-inflammatory effects [28]. Recent meta-analyses support the effectiveness of low-dose ATO both as a first-line treatment and to improve the effectiveness of the surgery [25]. ATO is associated with good recovery [28]. DEX has a synergistic effect with ATO where both drug levels increase in the hematoma and increase the anti-inflammatory effects through macrophage regulation [29].

10.4.3 Tranexamic Acid

Tranexamic acid (TXA) is a synthetic plasmin inhibitor that inhibits fibrin-plasminogen bonding [30]. TXA is found to be the second most effective single treatment after DEX in preventing cSDH recurrence and also the second best treatment in reducing hematoma volume after ATO [25, 28]. TXA has been shown to increase the incidence of epilepsy in a dose-relative manner indicating cautious use is advised [31].

10.4.4 Goreisan

Goreisan (GRS) is an inhibitor of aquaporin-4 found on the outer membrane of the cSDH. Goreisan is theorized to prevent fluid inflow into the cSDH resulting in the resolution of the hematoma [32]. However, some recent studies found little to no effect in preventing the recurrence of SDH [25, 30]. Harada et al. [33] found Goreisan to be effective in homogenous iso-dense type cSDH (Fig. 10.4), and less effective in other types of the disease.

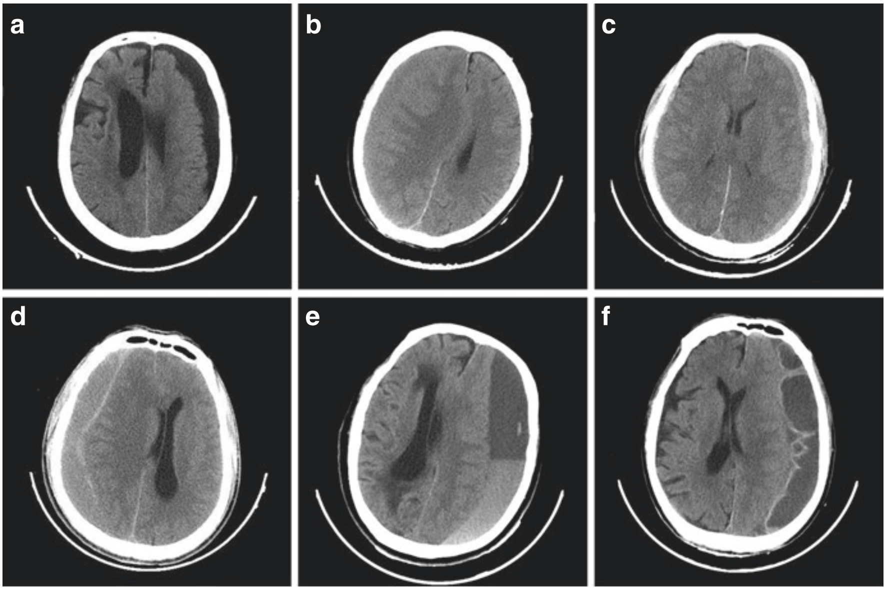

Fig. 10.4 Nakaguchi classification of cSDH. Homogenous hypo-dense (**a**), homogenous iso-dense (**b**), homogenous hyperdense (**c**), laminar (**d**), separated (**e**), trabecular (**f**) [34, 35]

10.5 Surgical Management of Subdural Hematoma in Pediatric Population

An aSDH is almost always associated with non-accidental traumatic injury in children [36, 37]. Other causes are trauma, surgical complications, fetal SDH, traumatic birth, aneurysm, arachnoid cyst, hematological diseases causing coagulopathy, glutaric aciduria, galactosemia, and hypernatremia [37]. Severe trauma may require conventional craniotomy/craniectomy and hematoma evacuation. If craniectomy is performed, future cranioplasty may be required due to physiologic growth of the skull and possible resorption of the bone flap [38].

If cSDH is seen in an infant, subdural tapping may be a viable option if the anterior fontanel is patent. The tapping point is the crossing of the mid-pupillary line and coronal suture of the anterior fontanel. The catheter is inserted approximately 1 cm posterior to the point and advanced subcutaneously and then turned 90° perpendicular to the skull. This subcutaneous advancement prevents cerebrospinal fluid leakage after tapping. Sudden decompression must be avoided.

External subdural drainage is an effective way to treat infantile cSDH [39]. External drainage is an effective way for cSDH treatment but increases the risk of infection, and catheter obstruction may complicate the treatment [39]. Another common technique is the placement of subdural shunts for hygromas and cSDH [40, 41]. Subdural to intraperitoneal or subdural to subgaleal shunts without a valve have been reported with success [40, 41]. While subdural shunts are reported to have lower recurrence rates than other procedures, a second surgery is almost always necessary for complications such as obstruction or infection or removal of the shunt after resolution of the hematoma [40, 41]. Hyperdense hemorrhage on computed tomography (CT) suggests that blood products may cause shunt occlusion in the future, and alternative methods could be considered [42].

Multiple membranes on imaging may require BHC or minicraniotomy. The technique is similar to that described above. The use of drainage has been reported with mixed results, and BHC seems to have a higher recurrence rate in contrast to adults [43, 44]. Minicraniotomy may be a better option in the pediatric population with a relatively lower recurrence rate, therefore fewer surgical interventions [44]. Creating a subgaleal pouch without using drainage may be a viable modification for lower recurrence rates in infants [45].

Low-dose dexamethasone and atorvastatin-combined treatment has been shown to resolve post-BDH recurrence in pediatric patients [46]. MMA embolization was also successfully demonstrated to be effective in treating recurred hematoma after BHC in an 18-month-old patient [47].

10.6 Conclusion

There are extensive research and ample meta-analyses regarding SDH in adult and geriatric patients in the literature. Optimal surgical intervention must be decided on a case-by-case basis. Considerations must be made on multiple factors such as the etiology of the hematoma, age, comorbidities of the patient, and CT findings. The optimal approach is still debatable, and recent advancements in the field have created a stir in the community. Thanks to recent advances in the TDC technique, it appears to have a similar success and recurrence rate to BHC. MMA embolization or therapeutic medical options such as low-dose dexamethasone and atorvastatin in combination may preclude surgical intervention in select patients or can be used to improve surgical success rates.

The pediatric population and infants have different characteristics and success rates for the same procedures compared to adults. Hence, different approaches are often used. Unfortunately, reports in this area are scarce, and the quality of evidence is far lower than that found in adults. Further research in the field is necessary for the development of standardized surgical guidelines.

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