Original Article

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Bedside Twist Drill Craniostomy for Chronic Subdural Haematoma: A Prospective Study

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Abstract

Context: The ideal surgical treatment of chronic subdural haematoma has not been clearly defined. The choice of intervention in most centres is largely based on the personal preference of the neurosurgeon. *Aims:* 1. To study the neurological outcome of twist drill craniostomy in patients with chronic subdural hematoma. 2. To study the efficacy of twist drill craniostomy in chronic subdural haematoma. *Settings and Design:* The prospective study was conducted in a single centre, in the department of neurosurgery of a teaching hospital in South India. *Methods and Material:* Seventy consecutive chronic subdural haematoma patients admitted from 15-January-2015 to 14-July-2016, needing operative intervention, were subjected to twist drill craniostomy. The diagnosis was confirmed by radiological means, with significant hemispheric haematoma on imaging. *Statistical analysis used:* Frequencies and percentages were calculated and Friedman test was applied. *Results:* There was significant clinical improvement in both Markwalder grading system and Glasgow coma scale after twist drill craniostomy within 24 hours of the intervention and in the regular follow up period. There were nine deaths [12.86%] in the study group. The recurrence rate was 18.57% among the operated subjects, and could be managed mostly by aspiration through the same drill hole. *Conclusions:* This therapeutic approach is suitable both for elderly and for medically frail patients who pose a high anaesthetic and operative risk. The major advantage of twist drill craniostomy was that it can be performed at the patient's bedside under local anaesthesia. The complication rate is as low as other modern surgical techniques.

Keywords: Chronic Subdural Haematoma; Twist Drill Craniostomy; Markwalder Grading System; Glasgow Coma Scale; Neurological Outcome.

Introduction

Chronic subdural haematoma [CSDH] is a frequently encountered neurosurgical problem, especially in the elderly. Adequate timely management brings out a favourable outcome in most of the subjects, many of whom have co-morbid conditions. But the management modalities generally depend on the preference of the neurosurgical expert, and could vary from medical management to various surgical interventions [1]. Twist Drill Craniostomy [TDC] is a relatively recently evolved procedure, used world-wide, and in a short period is preferred in certain categories of patients, especially in high risk cases [2]. The neurological outcome in CSDH patients treated by TDC was looked into, and the efficacy of the procedure was analyzed systematically in seventy patients, in a study over a period of eighteen months.

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Materials and Methods

Study Setting: The prospective study was conducted in a single centre, in the Department of Neurosurgery of a tertiary care teaching hospital. The procedure of TDC was done in all the subjects as a bed-side emergency maneuver in the Neurosurgery Intensive Care Unit, under local anaesthesia.

Study Population: The group comprised of seventy patients with CSDH, treated by TDC, during the one and a half year period between 15-01-2015 and 14-07-2016.

Inclusion Criteria

- All patients with CSDH confirmed by radiological means [Computed Tomography (CT) scan or Magnetic Resonance Imaging], showing significant hemispheric, CSDH (more than 10 mm thickness) needing operative intervention.

Exclusion Criteria

- Age below 18 years
- Thin subdural haematoma (SDH) (less than10 mm)
- Small or multi-loculated SDH
- Post-craniotomy SDH
- Recurrent collections after burr hole evacuation
- Radiological suspicion of subdural empyema
- Large, acute clot component (organized hyperdensity or mixed hyperdensity on CT scan).

Indications for TDC

After obtaining clearance from the Institutional Ethics Committee, the management of seventy CSDH patients chosen for operative intervention by TDC was followed up prospectively. Though the intervention was minimally invasive, it still had high risk elements, as it was done in 14 very elderly patients [over 80 years of age], in 22 patients on treatment for cardiac problems, and in eight patients with hepatic or renal failure, all not suitable for more invasive procedures. The neurological status of eight subjects was too poor to wait for the standard burr hole procedure.

Twist Drill Procedure

A point on the temporal line of the patients, corresponding to the maximum thickness of the haematoma was selected; almost always this corresponded with a point anterior to the coronal suture, considered safe for penetration of skull. Limited shaving of the scalp was done and the site was infiltrated with local anaesthetic agent. A scalp incision, about 0.5 cm long was put, and a hole was made on the skull [diameter four mm] using a hand operated twist drill machine. The depth of the drill hole could be adjusted so that it would not injure the brain. An external ventricular drainage system available in the market was utilized for the drainage procedure [Figure 1]. The ventricular catheter was introduced into the subdural space obliquely, and advanced to a length of not more than five centimetres [Figure 2]. The proximal part of the catheter was tunneled in the scalp along the subgaleal plane for a length of about five centimetres. The catheter was connected to a three way stopcock to which the external drainage system was connected. After draining 10 to 20 ml of subdural collection, irrigation with normal saline was initiated by adjusting the stopcock. Irrigation and drainage were continued till the effluent became clear. It was continued for 24 to 48 hours as per the requirement. CT scan was repeated six hours after the procedure [Figure 2], and the drainage system was removed later according to the nature of the effluent.

Outcome Measures

The primary outcome variable looked for was recurrence rate before or after discharge, which necessitated re-aspiration or surgery [burr hole aspiration or craniectomy]. This indication for re-intervention was clearly defined: before discharge, if the patient does not reach Markwalder grading scale 'zero' or 'one', with the CT scan showing residual fluid or air more than 10 mm in thickness, and a midline shift. After discharge, if there were recurrence or aggravation of symptoms [headache, motor or sensory involvement, alteration in higher functions], with a repeat CT evidence of significant residual fluid or air, it was again considered an indication for re-intervention. Secondary outcome variables included Markwalder neurological grading system and Glasgow coma scale, and radiological parameters at the time of admission, 24 hours after intervention, at 48 hours, follow up after three weeks, and three months. The Markwalder grading system and Glasgow coma scale were used for patient evaluation, so as to have a relevant comparison with similar studies. Frequencies and percentages are calculated and presented as tables for descriptive analysis. Friedman Test for repeated measures of non-parametric nature was applied for testing of hypothesis and statistical significance was declared when p-value was less than 0.05.

Results

The demographic profile of the subjects was noted at the time of admission. The type of injury leading to the CSDH was looked into [Table 1].

The time lag between the sustained trauma and the date of presentation to the hospital was also found to be variable. The mean period of time taken for seeking medical help after trauma was 7.94 (+ 2.87) weeks. Symptoms at the time of presentation in the outpatient department or casualty were grouped into various categories as depicted in Table 2.

In the radiological assessment, eight subjects (11.4%) had bilateral CSDH [Table 2]. In the unilateral haemorrhage group, the incidence was higher on the left side (34; 48.6%). Past medical history was significant in almost all cases. The commonest infirmity was cardiac arrhythmias, followed by dementia [Table 2].

All the subjects were on regular medication for different reasons [Figure 3], and these were noted as well. Majority of the patients were already on anticoagulants and/or antiplatelet drugs. The drugs could have contributed to the CSDH following minor injuries.

Detailed clinical examination of the subjects was done, along with a detailed haematological and coagulation profile and an assay of hepatic viral markers.

The volume of fluid drained out varied from 80 to 150 ml. Near-complete evacuation could be attained in most of the cases, except for small clots. There was a definite risk of serious injury to subjacent brain and cortical vessels, but this did not happen in our series. The most common complication met with in our study was catheter block, which was circumvented by manipulation of the drainage and the irrigation process. The same drill hole could be utilized for a repeat procedure in cases of recurrence.

Clinical Outcome

Neurological status of the subjects was assessed as per the Markwalder grading scale [Table 3] and Glasgow coma scale [Table 4] at the time of admission, after 24 hours of intervention, after 48 hours, and follow up at three weeks and three months.

There was significant improvement in both Markwalder grading system and Glasgow coma scale by twist drill craniostomy in most cases within 24 hours of intervention. After 48 hours of the procedure sixty three patients [90%] showed markedly improved neurological status. All probable postoperative complications were looked for.

Recurrence: During the post-operative stay in the hospital 13 patients had a recurrence of symptoms [recurrence rate 18.57%], and ten of them were managed by repeating the procedure through the same drill hole. In two patients a separate hole had to be drilled. One patient had to be subjected to mini-craniotomy as she developed fresh bleed with plenty of residual clots; pre-operatively this patient had altered coagulation profile secondary to myelodysplastic syndrome. In the follow up three weeks after TDC, burr hole aspiration had to be done for three patients, for re-accumulation of haematoma.

Mortality occurred in nine patients [mortality rate 12.86%], but these were not complications of the procedure as such. Of the nine, five subjects [7.1%] with pre-operative heart problems, succumbed to cardiac arrest in the post-operative period, and two patients [2.9%] from a fresh cerebrovascular accident. Two other patients had concomitant intracerebral haemorrhage [2.9%], a week after surgery in one patient, and three weeks after intervention in a patient with myelodysplastic syndrome.

Complications of the Procedure

Epidural/ subdural/ intracerebral haematoma: There was a definite risk of developing epidural as well as subdural haematoma during the procedure. In our study one patient revealed nominal epidural bleed, but this had practically no impact on the prognosis. Another patient developed a small intracerebral haematoma on the opposite hemisphere near the occipital lobe, possibly a venous haemorrhage resulting from sudden decompression of the subdural collection; this also could have been avoided by a careful slower decompression. In all our patients we had purposefully avoided rapid drainage of the subdural collection, but there was a sudden gush of subdural collection immediately after drilling the hole the latter patient. Though we tried to prevent the gush by thumb pressure, the procedure had to be continued. There was no significant improvement in the neurological status and the patient got discharged at request and was lost to follow up.

Post-operative infection: There was a single case of minor drill site infection, which was promptly controlled. We used a closed system of drainage and this was never kept for more than 48 hours after evacuation. Hence, in our series, subdural empyema never occurred.

Pneumocephalus: Many of the patients (53, 75.71%), on follow up scan showed minimal pneumocephalus, but none of them had any clinical symptom related to the condition, except one. This sole patient showed moderate pneumocephalus, and this resolved spontaneously with conservative management. There was not a single case of tension pneumocephalus. Our closed system of drainage and irrigation, thus has proved very unlikely to produce significant intracranial air trapping. The technique of removing the drainage tube was also important in preventing the development of pneumocephalus. The short incision was closely approximated abruptly after removing the drainage tube, and suturing was done with meticulous care.

Brain Penetration: In our series none of the subjects suffered significant brain injury at the time of drilling or drainage system placement, but two patients developed minimal cortical injury possibly related to catheter advancement along with stylet. This could have been avoided by very careful catheter positioning.

Seizures: Occurred in six patients, and was controlled by the standard antiepileptic regimen.

Catheter folding or kinking or block: This was actually the most common procedural problem encountered, but it could almost always be corrected by diligent care and patient manipulation of the tubings and connections. Catheter block was identified in one patient, and gentle manipulation of the connections could not relieve it. Ultimately it was managed by replacement with a new drainage irrigation system.

Catheter failure and inadequate drainage were common problems encountered during the procedure, and could be resolved in all subjects by gentle maneuvering of the drainage systems. Replacement of the tubing was required in one patient and this was due to a manufacturing defect in the tubings. Inadequate drainage in three patients was also managed by gentle manipulations of the tubings.

Table 1: Baseline characteristics of the patients

Characteristic	Frequency	Percentage
Sex of the patient		
Female	28	40
Male	42	60
Age in years		
51 – 60	11	15.7
61 – 70	22	31.4
71 – 80	23	32.9
81 – 90	11	15.7
91 – 100	3	4.3
Cause of injury		
Fall from height	3	4.3
Head trauma	41	58.6
Road traffic accident	9	12.9
Tripped over	14	20
Unknown	3	4.3

Table 2: Clinical parameters at the time of presentation

Parameter	Frequency	Percentage
Symptom		
Confusion	5	7.1
Decreased	9	12.9
Dizziness	4	5.7
Hemiparesis	27	38.6
Imbalance	15	21.4
Lethargy	8	11.4
Seizures	2	2.9
Laterality		
Bilateral	8	11.4
Left side only	34	48.6
Right side only	28	40.0
Co-morbidities		
AF & other arrhythmias	22	31.4
Chronic liver disease	8	11.4
Chronic renal failure	2	2.9
Cerebrovascular accidents	9	12.9
Dementia	13	18.6
Epilepsy	5	7.1
Myelodysplastic conditions	1	1.4
Parkinson’s disease	7	10.0
Transient Ischemic Attack	3	4.3

Table 3: Markwalder Grading Scale (MGS) after Twist Drill Craniostomy

MGS scale	At admission	After 24 hours	After 48 hours	After 3 weeks	After 3 months
0	-	6	9	11	11
1	11	23	30	39	39
2	29	27	19	11	11
3	25	7	4	-	-
4	5	7	8	-	-
Expired	-	-	-	9	9
Friedman Test: p-value < 0.0001					

Table 4: Glasgow Coma Scale (GCS) after Twist Drill Craniostomy

GCS score	At admission	After 24 hours	After 48 hours	After 3 weeks	After 3 months
8	1	2	3	-	-
9	1	1	1	-	-
10	4	4	3	-	-
11	12	-	-	-	-
12	15	6	6	3	3
13	25	27	27	20	14
14	12	28	28	35	41
15	-	2	2	3	3
Expired	-	-	-	9	9
Friedman Test: p-value < 0.0001					

Fig. 1: Instruments for twist drill craniostomy: drill machine, external ventricular drainage system, stopcock

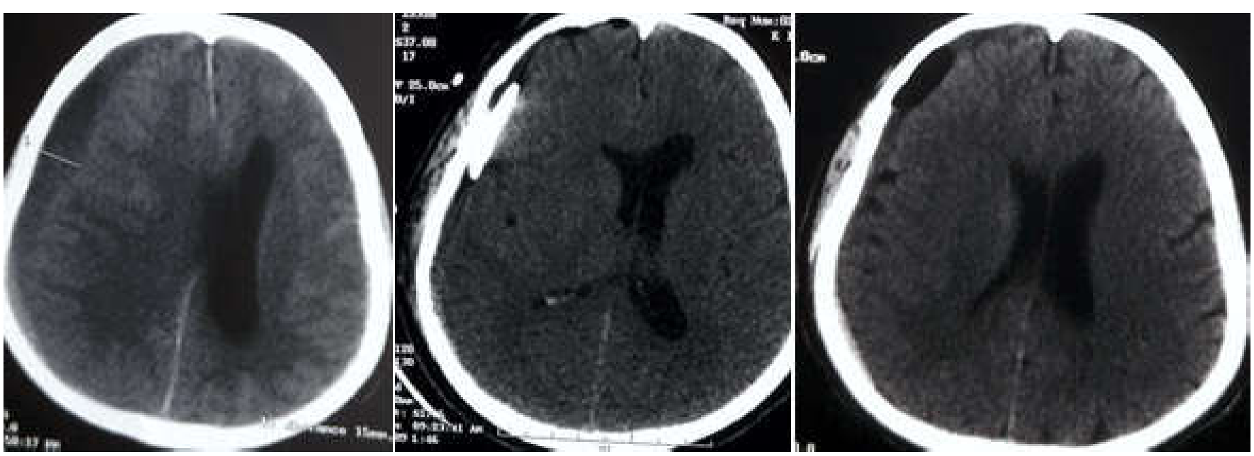

Fig. 2: Chronic subdural haematoma treated by twist drill craniostomy, Computed Tomography scan: pre-operative, 6 hours post-operative and 48 hours post-operatively

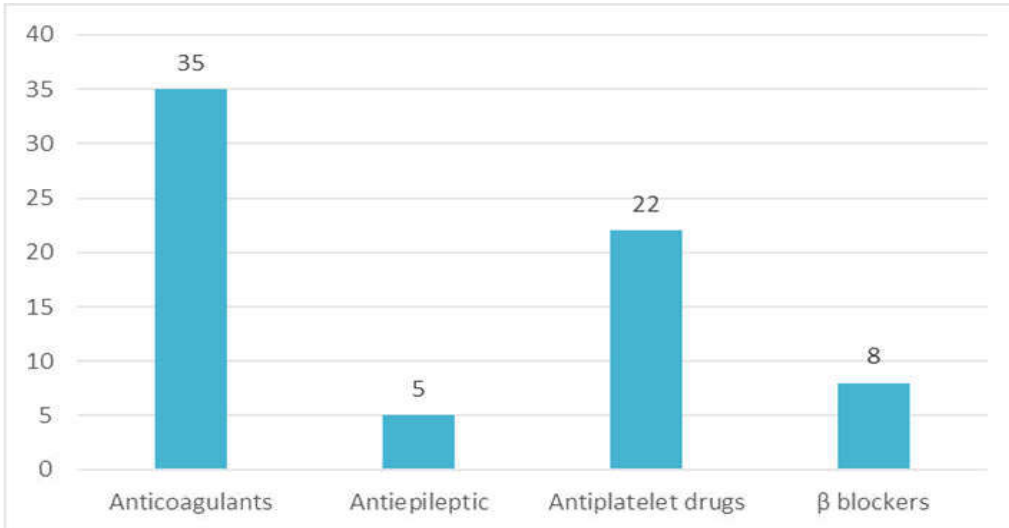

Fig. 3: Drug intake by the patient prior to the trauma

Discussion

Twist drill craniostomy (TDC) was first introduced as a diagnostic procedure in 1966 [1]. Ever since many studies have proved that TDC with a closed system drainage is a very effective treatment modality for CSDH. As per available literature, Burton C first reported the management of CSDH by twist drill craniostomy and aspiration of the haematoma in 1968 [2]. Bozkurt G et al state that the aim of the surgical management of CSDH is decompression of brain and removal of fibrinolytic substances from the area. This could be achieved by craniotomy and excision of subdural membranes, craniostomy with burr hole evacuation, neuro-endoscopic techniques, or TDC and drainage [3]. The elderly age of these patients place them at a higher risk due to concomitant medical problems. Sucu HK et al state that TDC technique being blind, there is a definite risk of complications, some of which include epidural haematoma, brain penetration and folding of the catheter. Also post-operative problems like infection, pneumocephalus, etc., may be encountered [4]. Inadequate drainage of the haematoma is another common complication.

Hwang SC et al studied the external carotid angiograms of forty SDH patients [5] and Crossman AR studied fifty skull radiographs [6] for assessing the course of middle meningeal artery in relation to the coronal suture, in an effort to determine a safe entry point for TDC. They concluded that no relevant arterial branch or vein or venous sinus was related anterior to the coronal suture at the level of superior temporal line. Reinges et al modified bedside TDC, making it more useful for subjects with poor neurological status [7]. After penetrating just the bone with the drill, a 14G Teflon cannula was made to perforate the duramater and the outer neo-membrane of the haematoma. Evacuation was done by spontaneous efflux and Valsalva maneuver with the patient placed in 30 degrees Trendelenburg position. The cannula was removed after the efflux, maintaining the patient in the same dependent position. Lee JY et al studied the indications and surgical results of TDC in 134 CSDH patients and concluded that the pre-coronal point, defined as a point one centimetre anterior to the coronal suture at the level of the superior temporal line, was a safe and effective entry point [8]. This point could easily be marked on brain CT pictures. First the outer table of skull was pierced perpendicular to the skull surface, and then the inner table and dura were pierced at an angle of about forty five degrees to the bone surface. They introduced a standard ventriculostomy catheter into the subdural space for passive haematoma evacuation into a ventricular drainage bag. In TDC procedure by Bozkurt G and team, after skull penetration, the dura was perforated with a 16G cannula, and the haematoma was discharged by spontaneous efflux, followed by Valsalva's maneuver, or positioning the patient in Trendelenburg position [3]. Placement of hollow screws after drilling the skull was put forth by Krieg SM and associates for decompressing the haematoma, but about 20% of such patients required burr hole surgery [9]. Being a blind technique, TDC carries a risk of haemorrhagic complications like epidural, subdural and intracerebral haematomas [4,10]. Smely C et al suggest that faulty placement of the drain could damage superficial cerebral vessels or bridging veins, and macro-capillaries in the outer neo-membrane of the CSDH]11]. According to Sucu HK and associates, bleeding from dural separation can be prevented by using pointed tip drill bit and giving a sudden push on dura to enter the subdural space [4]. Also Lee JY and team suggest that the drill is preferably twisted fast to penetrate the dura without separating it from the overlying bone [8]. To prevent dangerous bleeding complications during insertion of drainage tube, Yadav YR et al put forward a modified technique by coagulation of the dura mater [12]. We did not come across any significant unexpected bleeding in the present study.

Asfora WT and Schwebach put forward a modified twist drill technique, subdural evacuating port system (SEPS), which promotes brain expansion, and doesn't require irrigation [13]. Evacuation was done by gradual decompression using a uniform negative extradural pressure. The authors state that it is more effective in hypodense extradural collections. Kenning TJ reported that SEPS insertion has produced significant bleeding, though very rarely [14].

Sucu HK et al suggest that brain penetration could be avoided by increasing the angle of skull penetration [4]. Many authors like Hwang SC et al and Carlton CK suggest that inadvertent brain injury can be avoided by passing the catheter tangentially into the subdural space [5,15]. At the same time Hwang SC et al also observed that thickness of the haematoma shall be about double the thickness of the skull, for the subjects to become safe candidates for TDC. In 1998, in an effort to avoid brain penetration Reinges and team modified the mechanical drill system by a special self-controlling drill system and a pre-adjustable distance holder [16]. Yadav YR et al suggested that brain penetration during drilling could be prevented by selecting the drill site at the most curved surface [12]. So also using angled drill and curved introduction of catheter with the help of a guide wire by them prevented brain penetration on flat surface. In spite of all these precautions they report inadequate drainage in 14% cases. Angled drilling was done to reduce brain penetration by Sucu HK et al as well [4]. They used a special instrument with a guard, which allowed angled entry of about thirty degrees to the external surface of the skull. They suggested increasing the size of the catheter to prevent inadequate drainage of the haematoma. We did not encounter even a single case of brain penetration, but there were two cases of minor cortical injury which could have been avoided by better diligent care.

Post-operative pneumocephalus is a risk in all surgical interventions for CSDH, and it could possibly result in raised intracranial pressure, as commented by Ram Z et al [17]. According to Reinges et al, this risk could be reduced by spontaneous closure after removing the cannula promptly at the end spontaneous efflux, with the patient in Trendelenburg position [7]. But the method has a risk of associated subdural bleeding, intracerebral bleeding, subdural empyema and insufficient evacuation. This complication was never encountered by us.

Catheter failure is due to its inappropriate positioning, and could occur due to its malposition in the epidural space according to Sucu HK et al [4]. Lee JY and team reported two cases of catheter failure, and suggest confirmation of proper catheter position by ensuring crank-oil colour fluid draining out [8]. Yadav YR et al suggested insertion of catheter using a guide wire, a curved malleable wire, to prevent catheter folding or kinking [12]. Sucu HK et al used Kirschner wires for the same purpose [4].

Irrigation of the subdural space with fluid containing tissue plasminogen activator [tPA] was suggested by Neils DM et al [18]. This method, according to the authors, would help reduce inadequate drainage. Sucu HK et al suggest that inadequate drainage can be prevented by using a larger diameter irrigation catheter passing through large sized drill holes [4].

Lee JY et al noted that in cases of recurrent haemorrhage, the density of the haematoma was higher compared to the initial pre-operative density.8 So also the incidence of pneumocephalus was reportedly higher. Even though mild pneumocephalus was a very common occurrence in our study, it was never clinically significant and never called for any intervention. In cases of recurrence, all patients studied by Lee JY et al were treated by burr hole evacuation [8] as against our study where drainage in the post-operative hospital stay was by repeated evacuation through the TD craniostomy itself. Recurrence after three weeks was managed by burr hole aspiration.

Continuous catheter drainage and irrigation of subdural space carries a risk of infection. Incidence of wound infection, meningitis and subdural empyema reportedly varied between 01-18% [11,17,19]. According Reinges et al the risk of infection is reducible by reducing the maximum number of subdural taps before changing the treatment protocol [7]. They suggest it should be less than five taps in unilateral and ten taps in bilateral CSDH respectively, and report that 92% and 95% of patients were successfully treated in this manner.

We strongly recommend bed side TDC under local anaesthesia for patients who would not stand the risk of anaesthesia due to co-morbid conditions, in those who cannot wait for anesthesia due to a deteriorating neurological status and those who cannot afford the operation and anaesthesia expenses. Reinges et al recommend bedside percutaneous subdural tapping and spontaneous haematoma efflux under local anaesthesia as the first and minimally invasive attempt in CSDH, especially in patients with poor general condition [7]. They suggest that more invasive treatments with higher procedure related morbidity could be reserved for cases in which this modality of surgical intervention fails.

Bozkurt G et al managed failure of clinical improvement after repeated subdural taps treating secondarily by membranectomy after craniotomy [3]. Markwalder's review suggested that craniotomy as a radical approach has to be reserved for cases in which subdural collection re-accumulates, or in case of solid haematomas, or if brain fails to expand and obliterate the subdural space [20]. We agree fully with the suggestion by Reinges et al that patients having extensive septations or a significant hyperdense component on brain CT scan shall be excluded from TDC regimen.

The neurological status of the subjects was always considered the decisive factor for postoperative CT evaluations and further treatment modalities in the present study, and was not based solely on scan reports. This is in conformity with the observations of Markwalder TM et al and Bozkurt G et al. [3,20]. Clinical observation formed the most dependable criterion for patient evaluation in all cases.

Conclusion

Twist drill craniostomy is a safe, reliable, cost-effective modality of surgical management in chronic subdural haematoma patients, with acceptable neurological outcome. The risk of the procedure is not more than that of other surgical procedures. This should be the first line of management in elderly patients with poor neurological status and general health, and those with many co-morbid conditions and risk factors. With advancing life expectation and regular antiplatelet/anticoagulant therapy advocated, patients with this clinical condition can only be expected to increase in numbers. More invasive surgeries can be preserved for younger patients with better general health, and in cases of multiple recurrences.

Acknowledgement

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Key Messages

Timely management of chronic subdural haematoma in the elderly often provide a favourable outcome.

Co-morbid conditions in the aged people can be contra-indications for anesthesia and invasive procedures.

Clinical scores improved in 24 hours in a majority of cases.

Recurrence was managed by repeating the procedure through the same drill hole in under 20% of the patients.

Twist drill craniostomy provides a safe and effective alternative for critically ill elderly with subdural haematoma.

Conflict of Interest

None.

References

1. Rand BO, Ward AA Jr, White LE Jr, White LE Jr. The use of the twist drill to evaluate head trauma. J Neurosurg 1966;25:410-415.
2. Burton C. The management of chronic subdural hematoma using a compact hand twist drill. Mil Med 1968;133:891-895.
3. Bozkurt G, Ayhan S, Akbay A, Palaoglu S. Treatment of chronic subdural haematoma by twist drill craniostomy with irrigation. Turkish Neurosurgery 2006;16(1):19-24.
4. Sucu HK, Gokmen M, Ergin A, Bezircioglu H, Gokmen A. Is there a way to avoid surgical complications of twist drill craniostomy for evacuation of a chronic subdural hematoma? Acta Neurochir (Wien) 2007;149:597-599.
5. Hwang SC, Im SB, Kim BT, Shin WH. Safe entry point for twist drill craniostomy of a chronic subdural haematoma. J Neurosurg 2009;110:1265-1275.
6. Crossman AR. Cranial meninges, in Standring S (ed): Gray's Anatomy: The Anatomical Basis of Clinical Practice, ed.39. London: Elsevier;2005:275–285.
7. Reinges MH, Hasselberg I, Rohde V, Kuker W, Gilsbach JM. Prospective analysis of bedside percutaneous subdural tapping for the treatment of chronic subdural haematoma in adults. J Neurol Neurosurg Psychiatry 2000;69:40-47.

8. Lee JY, Kim BT, Hwang SC, Im SB, Shin DS, Shin WH. Indications and surgical results of twist drill craniostomy at the pre-coronal point for symptomatic chronic subdural haematoma patients. J Korean Neurosurg Soc 2012;52:133-137.

9. Krieg SM, Aldinger F, Stoffel M, Meyer B, Kreutzer J. Minimally invasive decompression of chronic subdural haematomas using hollow screws: efficacy and safety in a consecutive series of 320 cases. ActaNeurochir (Wien) 2012;154:699-705.

10. Lee CW, Hwang SC, Kim BT, Lee SY, Im SB, Shin WH. [Treatment results of twist-drill craniostomy with closed system drainage for the symptomatic chronic subdural hematomapatients]. J Korean Neurosurg Soc 2005;37:282–286.

11. Smely C, Madlinger A, Scheremet R. Chronic subdural haematoma-a comparison of two different treatment modalities. ActaNeoruchir (Wien) 1997;139:818-826.

12. Yadav YR, Yadav S, Parihar VS. Modified twist drill technique in the management of chronic subdural haematoma. Turkish Neurosurgery 2013;23(1):50-54.

13. Asfora WT, Schwebach L. A modified technique to treatchronic and sub-acute subdural hematoma: Technical note. Surg Neurol 2003;59:329-332.

14. Kenning TJ, Dalfino JC, German JW, Drazin D, Adamo MA. Analysis of the subdural evacuating port system for the treatment of subacute and chronic subdural hematomas. J Neurosurg 2010;113:1004-1010.

15. Carlton CK, Saunders RL. Twist drill craniostomy and closed system drainage of chronic and subacute subdural hematomas. Neurosurgery 1983;13:153–159.

16. Reinges MH, Rubben A, Spetzger U, Bertalanffy H, Gilsbach JM. Minimally invasive bedside craniotomy using a self-controlling pre-adjustable mechanical twist drill trephine. Surg Neurol 1998;50:226-229.

17. Ram Z, Hadani M, Sahar A, Spiegelmann R. Continuous irrigation-drainage of the subdural space for the treatment of chronic subdural hematoma: a prospective clinical trial. Acta Neoruchir (Wien) 1993; 120:40-43.

18. Neils DM, Singanallur PS, Wang H, Tracy P, Klopfenstein J, Dinh D, Elwood PW, Fassett D, McCall T, Lin J, Tsung A. Recurrence-free chronic subdural hematomas: a retrospective analysis of the instillation of tissue plasminogen activator in addition to twist drill or burr hole drainage in the treatment of chronic subdural hematomas. World Neurosurg. 2012;78 (1-2):145-9.

19. Weisse A, Berney J. Chronic subdural haematomas: Results of a closed drainage method in adults. Acta Neoruchir (Wien) 1994;127:37-40.

20. Markwalder TM. The course of chronic subdural hematomas after burr-hole craniostomy with and without closed-system drainage. Neurosurg Clin N Am 2000;11:541-546.