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Original Article

Trepanation revisited in COVID-19 era: A perspective on craniotomy during current pandemic, surgical technique, and complications avoidance

Gopal Krishna, Ishwar Singh

Department of Neurosurgery, Pt B.D. Sharma Univerity of Health Sciences, Rohtak, Haryana, India.

E-mail: *Gopal Krishna - gopalblue222@gmail.com; Ishwar Singh - drishwarsingh@yahoo.co.in

***Corresponding author:**
Gopal Krishna,
Department of Neurosurgery,
Pt B.D. Sharma University
of Health Sciences, Rohtak,
Haryana, India.

gopalblue222@gmail.com

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ABSTRACT

Background: Craniotomy creates maximum aerosols threatening the health care workers (HCWs) of operation room. The technique of trepanation and measures to avoid complications has never been described in the literature. The time taken for craniotomy by different instruments has also never been compared.

Methods: The study included only COVID-positive patients who underwent surgery. Craniotomy was performed using trephine, pneumatic/power drill (PD), and Hudson brace-Gigli saw (HB-GS). Trepanation as done in 32 patients. The generation of aerosols and time taken for craniotomy by these instruments was observed. The droplet spread over a waterproof graph paper of 10 × 10 sq. cm was calculated in 13 cases of all the three craniotomy methods. The technique of trepanation and maneuvers to overcome complications was discussed.

Results: There was a gross difference in aerosol production and soiling of the surgical drapes, floor, surgeon's glove, gowns, face shield, goggles, etc. The average number of droplet aerosol in trepanation group was 4.76, 23.6 in drill and 21.3 in Gigli saw method. The average time taken for trepanation, PD, and HB-GS craniotomy was 4.8, 22.8, and 24.4 min, respectively. One mortality secondary to COVID was noted. All the HCWs assisting trepanation were negative for COVID-19 during postoperative follow-up of 7 days. However, 13 members of the surgical team which assisted in electric drill and HB-GS methods were COVID-positive.

Conclusion: Trepanation should be the preferred method of craniotomy during COVID-19 pandemic as it is associated with the least aerosolization and is the most time efficient.

Keywords: Aerosol, COVID-19, Craniotomy time, Trepanation, Trephine

INTRODUCTION

The COVID-19 is presently the most prodigious health concern of the globe. A cluster of pneumonia cases with unknown etiology was first reported in Wuhan city of China on December 31, 2019.[16] Since the first characterization of the virus, extensive research has been carried out all over the world. COVID-19 has affected 360 million people and caused more than 6.2 million deaths worldwide[15] till January 6, 2022, and current trends do not favor imminent amelioration.

The patients who need surgery have to be accordingly dealt with. This, however, is a threat to the surgeons and other health care workers (HCWs) in the present crisis. The present study attempts to develop a surgical strategy that can help mitigate the risk of novel coronavirus transmission.

The author utilized trepanation, the earliest practice of craniotomy in neurosurgery in this COVID era.

Around the globe, craniotomy is being done using a pneumatic/electric/power drill (PD) which generates excessive aerosols. There is no consensus among the neurosurgeons regarding the preferred method of craniotomy during the pandemic. Gupta *et al.* in their consensus statement from India have advised the use of Hudson brace-Gigli saw (HB-GS).[6] However, the author finds the use of Gigli saw associated with high aerosol generation albeit lesser than PD. Again, there is no literature regarding the use of trephine during COVID pandemic. This is also the first study in the literature that has described the technique of trepanation in detail and also discussed measures to avoid possible complications. There is a paucity of literature regarding the time taken for craniotomy by various

Table 1: Time taken for craniotomy in different cases.

S. No.	Instrument	Diagnosis	Type of craniotomy	Time taken (min)	Number of droplets
1.	Trepanation	Right frontal EDH	Right frontal craniotomy and EDH evacuation	3.2	5
2.		Left frontal EDH	Left frontal craniotomy and EDH evacuation	2.4	3
3.		Right frontotemporal EDH	Right frontotemporal craniotomy and evacuation	2.7	6
4.		Left parietal EDH	Left parietal craniotomy and evacuation of EDH	3.9	7
5.		Right parietotemporal EDH	Right parietotemporal craniotomy and evacuation	4.1	3
6.		Right frontotemporoparietal SDH	FTP craniotomy and lax duraplasty	5.4	5
7.		Left frontotemporoparietal SDH	FTP craniotomy and lax duraplasty	6.3	4
8.		Right frontotemporal EDH	Frontotemporal craniotomy and EDH evacuation	6.7	3
9.		Left frontotemporal EDH	Left frontotemporal craniotomy and EDH evacuation	6.1	4
10.		Right parietal glioma	Parietal craniotomy and gross total excision	4.3	5
11.		SAH with ruptured MCA aneurysm	Right frontotemporal craniotomy and clipping	8.4	6
12.		Right frontal glioma	Frontal craniotomy and GTE	4.2	3
13.		Right frontotemporoparietal SDH	FTP craniotomy with SDH evacuation and lax duraplasty	5.6	9
1.	Pneumatic drill	Left frontotemporal EDH	Frontotemporal craniotomy and EDH evacuation	17.3	21
2.		Left frontal EDH	Frontal craniotomy and EDH evacuation	15.2	23
3.		Right frontotemporoparietal SDH	FTP craniotomy and SDH evacuation	21.6	25
4.		Right frontotemporoparietal SDH with frontal contusion	Right decompressive craniotomy and contusectomy	20.3	28
5.		SAH with ruptured Acom aneurysm	Pterional craniotomy and clipping	22.4	22
6.		Right frontotemporal EDH	Frontotemporal craniotomy and EDH evacuation	25.3	24
7.		Left parietotemporal EDH	Frontotemporal craniotomy and EDH evacuation	23.2	20
8.		Right parietal EDH	Right parietal craniotomy and EDH evacuation	22	23
9.		Left temporal EDH	Left temporal craniotomy and EDH evacuation	20.7	24
10.		SAH with ruptured Acom aneurysm	Rt pterional craniotomy and clipping	28.6	22
11.		Left temporal glioma	Frontotemporal craniotomy and gross total excision	27.2	21
12.		Right middle 1/3 parasagittal meningioma	Right parietal craniotomy and NTE	23.3	31
13.		Left Frontotemporal SDH	Frontotemporal craniotomy and SDH evacuation	29.1	23
1.	Hudson brace and Gigli saw	Left frontal EDH	Frontal craniotomy and EDH evacuation	18	11
2.		Right frontotemporal EDH	Frontotemporal craniotomy and EDH evacuation	23.2	15
3.		Right frontotemporoparietal SDH	FTP craniotomy and evacuation of SDH with lax duraplasty	25.2	22
4.		Right temporal glioma	Right temporal craniotomy and gross total excision	18.6	24
5.		Left temporal meningioma	Left frontotemporal craniotomy and grade 1 excision	21.2	21
6.		Right frontotemporoparietal SDH with temporal contusion	Right decompressive craniotomy with contusectomy	26.6	34
7.		Left MCA bifurcation aneurysm	Pterional craniotomy with clipping	24.5	24
8.		Right frontal convexity meningioma	Frontal craniotomy and Grade 1 excision	23	23
9.		Left frontal EDH	Frontal craniotomy and EDH evacuation	22.1	16
10.		Left FTP SDH with contusions	Left decompressive craniotomy with contusectomy	28.6	20
11.		Right frontal EDH	Frontal craniotomy and EDH evacuation	20.1	19
12.		Left parietooccipital SDH with contusion	Left decompressive craniotomy with lax duraplasty	27.2	27
13.		Right temporal contusion	Right decompressive craniotomy with lax duraplasty	26.5	21

EDH: Extradural hematoma, SDH: Subdural hematoma, SAH: Subarachnoid hemorrhage, MCA: Middle cerebral artery, GTE: Gross total excision; NTE: Near total excision; FTP: Frontotemporoparietal

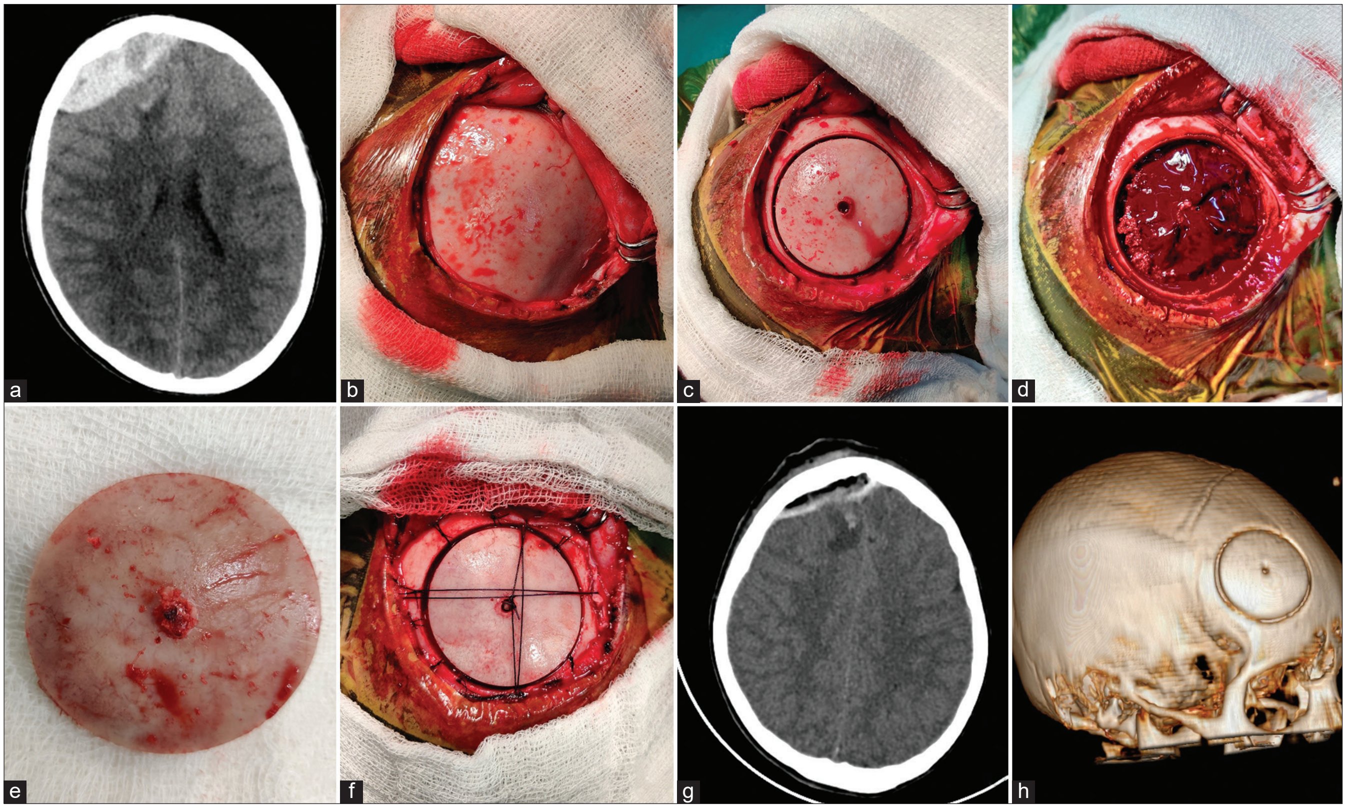

Figure 1: NCCT head showing right frontal extradural hematoma (EDH) crossing midline an extending toward left (a), intraoperative photographs exposure of the right frontal bone (b), trephination *in situ* (c), EDH seen (d), the central pinhole on the outer cortex of the bone flap which is an initial fixation point for trepan (e), EDH evacuated and bone flap fixed using sutures (f), postoperative CT scan showing resolution of EDH (g), and postoperative 3D reconstructed image (h).

Table 2: Number of cases according to broadly classified categories.

Diagnosis	No. of cases
Traumatic brain injury	
EDH	14
SDH	6
Depressed fracture	2
Neuro-oncology	
Glioma	5
Meningioma	2
Vascular (MCA aneurysm)	1
Infective (Osteomyelitis)	2

EDH: Extradural hematoma, SDH: Subdural hematoma, MCA: Middle cerebral artery

instruments. The author compared craniotomy time through different methods. Through this article, we share our experience with trephine craniotomy during the COVID pandemic.

MATERIALS AND METHODS

The study was conducted at a referral government establishment in North India. The article is found on the experiences of neurosurgeons, anesthetist, residents, nurses, and other assistants working in the operative environment. The study was conducted only on COVID-positive patients who underwent surgery. All the surgeries were conducted as per strict COVID prevention institutional protocol and using personal protective equipment.

Different methods of craniotomy

The aerosols of different sizes (<1–100 µm or greater) are formed during craniotomy. The visuals of droplets on craniotomy are frightful for the surgeons and assistant HCWs in addition to COVID risk in the present pandemic. The authors used trephine craniotomy and compared with electric craniotome and HB-GS.

For objective assessment, the droplet count was performed using microscope under 10 ×. The number of droplets was calculated on 10 × 10 sq.cm sheet. The graduated graph sterile paper was fixed at a distance of 20 cm away from the highest cranial incision point. The number of droplets have been compared in Table 1. The droplets which settled on the measurement paper were counted. The study did not assess the particles which might have remained suspended in the

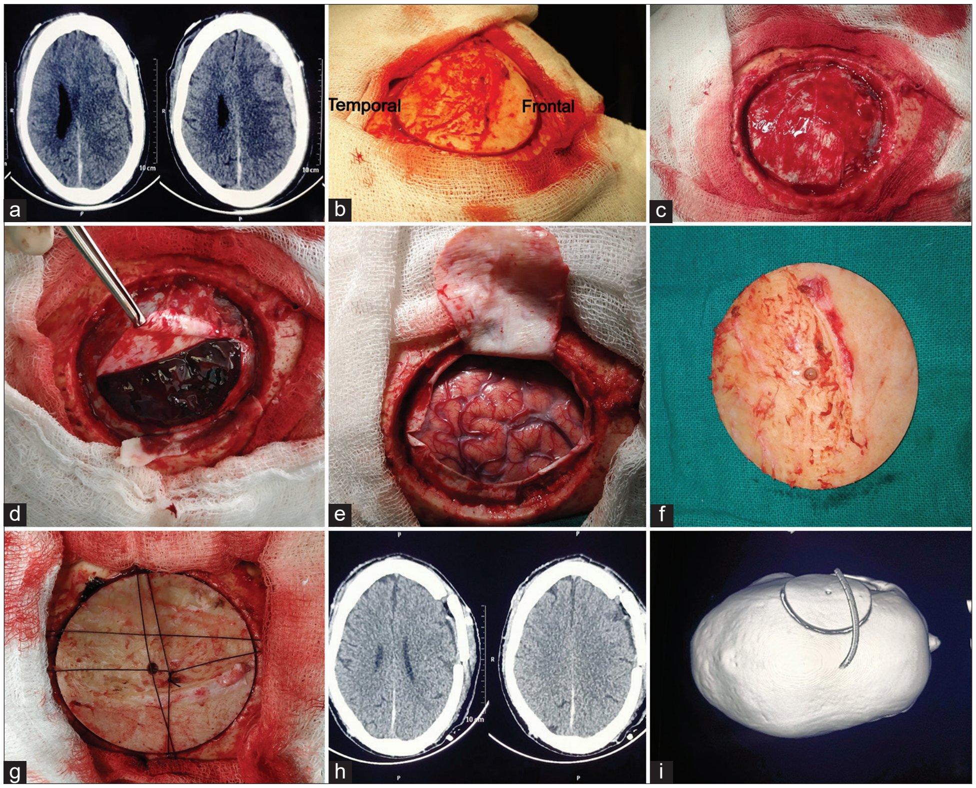

Figure 2: The left-sided frontotemporoparietal acute SDH with mass effect (a), intraoperative view of exposure and trephination (b and c), acute SDH seen (d), SDH evacuated and brain lax (e), bone flap secured using sutures (f and g), postoperative CT shows resolution of SDH and mass effect (h), and 3D bone flap *in situ* (i). SDH: Subdural hematoma.

Table 3: Trepanation in cases according to the anatomical location. (Cases of SDH and MCA aneurysm not included in this table).

Location	Diagnosis				
	EDH	Glioma	Meningioma	Depressed #	Osteomyelitis
Frontal	4	2	1		1
Parietal	3	2		1	1
Frontotemporal	3			1	
Posterior fossa	1				
Parietotemporal	3	1			
Parasagittal			1		

SDH: Subdural hematoma, EDH: Extradural hematoma, MCA: Middle cerebral artery

air. The fixed sheet was removed when craniotomy gets completed. The droplets were measured in total of 39 cases, 13 for each three types of instruments.

Time factor

The time taken for craniotomy by trepanation was observed and compared with the time taken by PD and HB-GS. The time was calculated from bone exposure till the bone flap was elevated. Time was recorded in 13 cases each of trepanation, PD craniotomy, and HB-GS craniotomy.

RESULTS

In this study, 32 cases underwent trepanation, 13 cases PD and 13 cases HB-GS. Of these, 22 cases underwent trepanation for traumatic brain injury. The distribution of cases is shown in Table 2. In respect to trepanation, the traumatic brain injury cases comprised 68.7% whereas nontraumatic cases 31.3%. The authors found trepanation in extradural hematoma (EDH) very simple [Figure 1]. EDH (43.7%) was the most common pathology in the present study.

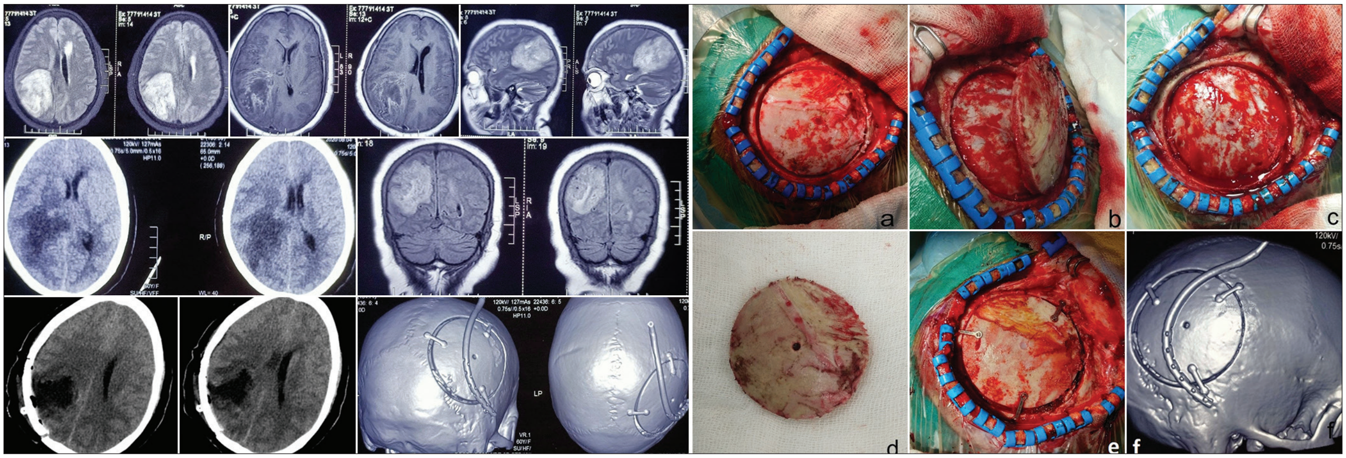

Figure 3: CT shows hypointense lesion in the right parietotemporal region with perilesional edema. The MRI was suggestive of a mass which was hypo on T1 and hyper on T2 sequence with heterogeneous enhancement on contrast. The findings were consistent with high-grade glioma (upper two rows). The lower row shows gross total excision of tumor on postoperative CT scan and 3D bone flap *in situ*. Intraoperative images showing trepanation over parietal bone (a), bone flap being lifted (b), craniotomy and bone flap (c and d), bone flap fixed using miniplates and screws (e), and 3D reconstructed image shows well-fixed bone flap in postoperative scan (f).

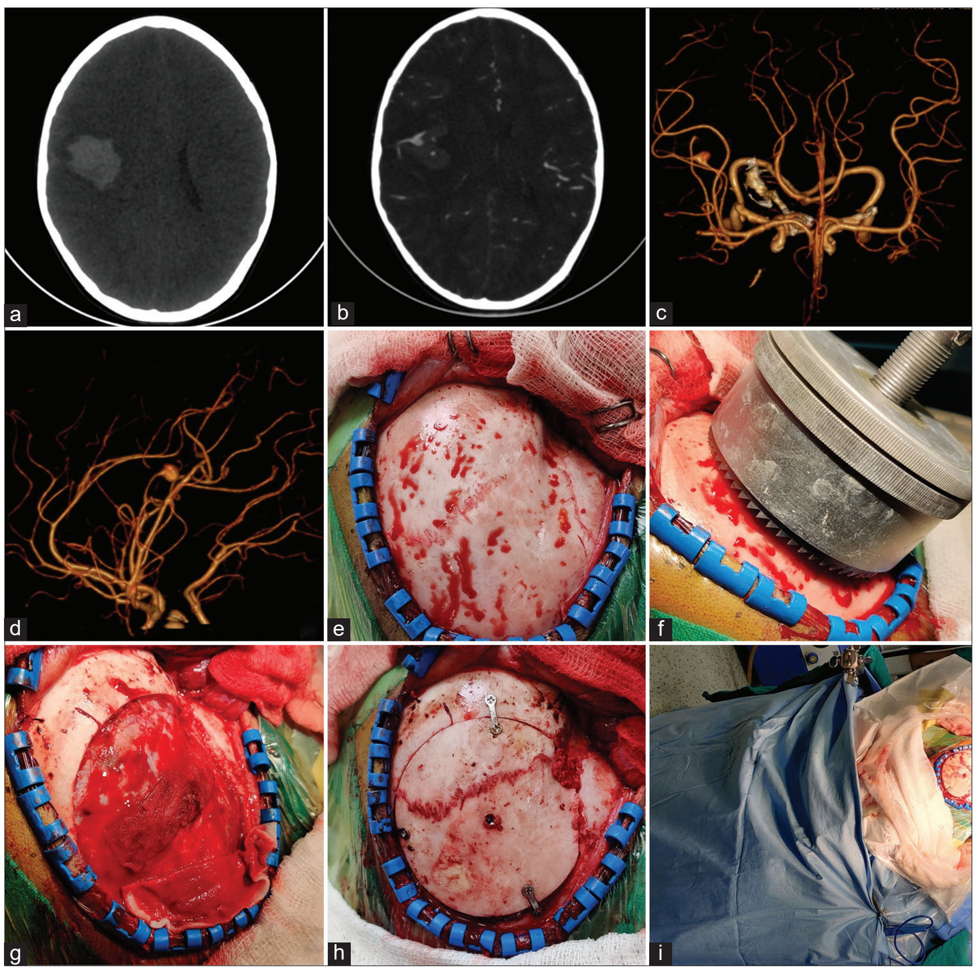

Figure 4: NCCT head shows subarachnoid hemorrhage with intracerebral hemorrhage in the right posterior frontal lobe (a), M3 middle cerebral artery aneurysm seen on CT angiography (b-d), intraoperative FST exposure with trepan (e and f), status post craniotomy (g), bone flap fixed using plates and screws (h), and operative field neat and clean during entire procedure (i).

Table 4: Mean time for craniotomy by different set of instruments.

Craniotomy instrument	Mean time (in min)
Pneumatic/electric drill system	22.8
Hudson brace and Gigli saw wire	24.4
Trepanation	4.8

The authors selected only those cases of acute subdural hematoma (SDH) for trepanation [Figure 2] which had no associated contusions. The cases of acute SDH were operated using large sized trepan. Lax duraplasty was done after evacuation of SDH in all the cases. Bone flap was repositioned. The case of acute on chronic SDH (CSDH) involved frontotemporoparietal region. The acute component was thick and significant so a plan of trepanation was made. A trephine craniotomy technique was used by Beatty in both acute and CSDH in 1999.[1] However, the dura was not closed and bone plate was not replaced in the study.

The cases of neuro-oncology were operated on because of recurrent seizures, altered sensorium, and onset of neurological deficits [Figure 3].

The case of middle cerebral artery (MCA) aneurysm involved M3 segment of the MCA in an 8-year-old child [Figure 4]. The aneurysm had its origin in one of the branches of the M3 segment of MCA. The trepanation involved the posterolateral part of the sphenoidal bone and frontosphenotemporal (FST) craniotomy was made. The craniotomy provided enough working area in the distal Sylvian fissure for dissection and an opportunity for temporary clip application.

The frontal bone (25%) was the most common location for trepanation in the present study followed by parietal (21.8%). The contour of parietal and frontal bone is favorable for the instrument and the surgeon does not need to change the long axis of the instrument. This is particularly useful for new surgeons recently exposed to trepanation. The anatomical location of various pathologies is described in Table 3.

Gross observations

The authors noticed a gross reduction in aerosol production compared to other methods of craniotomy. The surgical drapes, floor, surgeon's glove, gowns, face shield, and goggles remained clear; the surrounding environment of cranium too remained grossly free from aerosols. The use of HB-GS wire produced aerosols of large sizes during cutting motions. However, PD generates higher number of aerosol compared to Gigli saw.

Aerosolization measurement

The number of droplets was least in trephine craniotomy [Table 4]. The average number of droplet aerosol was 4.76 in trepan group of patients. The number of droplets in PD was 4.9 times higher compared to trepanation. The aerosolization in Hudson brace group was 4.47 times high compared to trepanation. The authors experienced that aerosols of smaller sizes which remain suspended in air are highest in PD. However, the same could not be quantified with the method used in this study. However, particle counting sensors can measure it to some extent.

Craniotomy time

The mean time taken during various methods of craniotomy is shown in Table 4. The time take for craniotomy by PD system was more than 4 times (4.75) the trepanation. The same done by HB-GS took 5.1 times more than the trepanation. The average time taken for trepanation in cases of EDH is 4.1 min. The time taken for craniotomy in various cases is shown in Table 1.

Complications specific to trepanation

Dura tear occurred in one case during craniotomy. The dura tear was very small. It was seen in the right M3 MCA aneurysm. However, it was repaired well at the time of closure. No parenchymal or vessel injury was encountered.

Mortality related to COVID in the present study

The study had one death postoperatively related to COVID acute respiratory distress syndrome in the case of temporoparietal glioma.

Follow-up of health-care professionals

None of the HCWs including of trepanation group were found affected with COVID-19 both clinically and on testing. However, a total of 13 team members were found COVID-positive who assisted craniotomy with PD or HB-GS craniotomy methods over the entire length of the study. The positive members were residents and nurses.

DISCUSSION

Craniotomy using trepan

The "vertibulum" used by Berengario was a prelude to modern craniotomy instruments.[3] Trepanation is the most ancient form of surgical practice since the prehistoric age.[7,9] The oldest trepanned specimens have been found in Africa and Europe dating 10,000 BC.[9,11] Most trepanned skulls have been found in Peru, Bolivia, West Europe, and North America.[4,9,13]

Trepanation has a great history as mentioned from the times of Hippocrates and was perpetuated by Galen in Roman times.[2,10] The exact timeline of the practice remains an enigma. Since the acquisition of the first trepanned skull of the pre-Columbian period which was studied by Paul Broca, a surge in the analysis of a large number of trepanned skulls was seen.[4,5] In prehistoric times, it is generally believed to be done for traumatic head injuries, brain tumors, infection, seizures, insanity, and protection from evil spirits lodged within the brain.[4,5,7,9]

Multiple prehistoric techniques included abrasion or scraping technique; grooving; drilling and cutting, and rectangular or polygonal intersecting incisions.[5,9,13] The infrequent trepanation over the midline, suboccipital, and temporal bone reflects the surgeon's awareness of structures and risks involved.[8]

It was used in modern times by Egas Moniz for psychosurgery.[14] The change in paradigms related to craniotomy and its safety occurred way back in the late 20th century. The gradual refinement in the hardware equipment and evolution of modern neurosurgery has made trepanation mainly obsolete especially in developed countries. In contemporary primitive cultures, trepanation in the 20th century is still performed, especially by Kisii and Tende tribes in East African countries and Arab tribes of North Africa.[5,9,12]

The modern neurosurgery has submerged the art of trepanation and also abandoned this glorious instrument. The craniotomy in neurosurgery is a basic step yet most perilous which carries the highest potential for COVID transmission among all aerosol-generating medical procedures besides, surgery on aerodigestive tract. The specialty of neurosurgery demands extensive bone work and drilling process which poses health risk. The use of pneumatic or electric craniotome and drill systems creates excessive aerosol comprising bone dust, blood, and irrigating fluid.

Understanding trepanation

Assembling the trepan

The instrument

The author uses Dass skull trephine (AVM-NA-705 from AVM health care). This instrument has a dura guard with a graduated scale and retractable centring drill. The cutting part of the instrument has a high-speed cutting blade. The length is 3.75 inches (95 mm) and has got diameters of different sizes (1.5, 1.75, 2, 2.25, 2.5, and 3 inches) to fit for the need of variable dimensions of craniotomy required [Figure 5].

Steps of cutting jaw adjustment and setting up of trephine

The trephine is rarely used in present times. Hence, the new generation of neurosurgeons is mostly oblivious of its use and technique of using the instrument. We briefly discuss here how to use it.

Measure the thickness of the bone provisionally planned for craniotomy on graduated film or computed radiography (console). The thickness of the bone should be measured at all the points of planned craniotomy. The minimum thickness of bone measured will be used to set up the cutting blade. The minimum thickness is taken to prevent the dura tear during craniotomy. The shape of trephine is in the form of two cylinders. The outer smooth dura guard and inner sharp high-

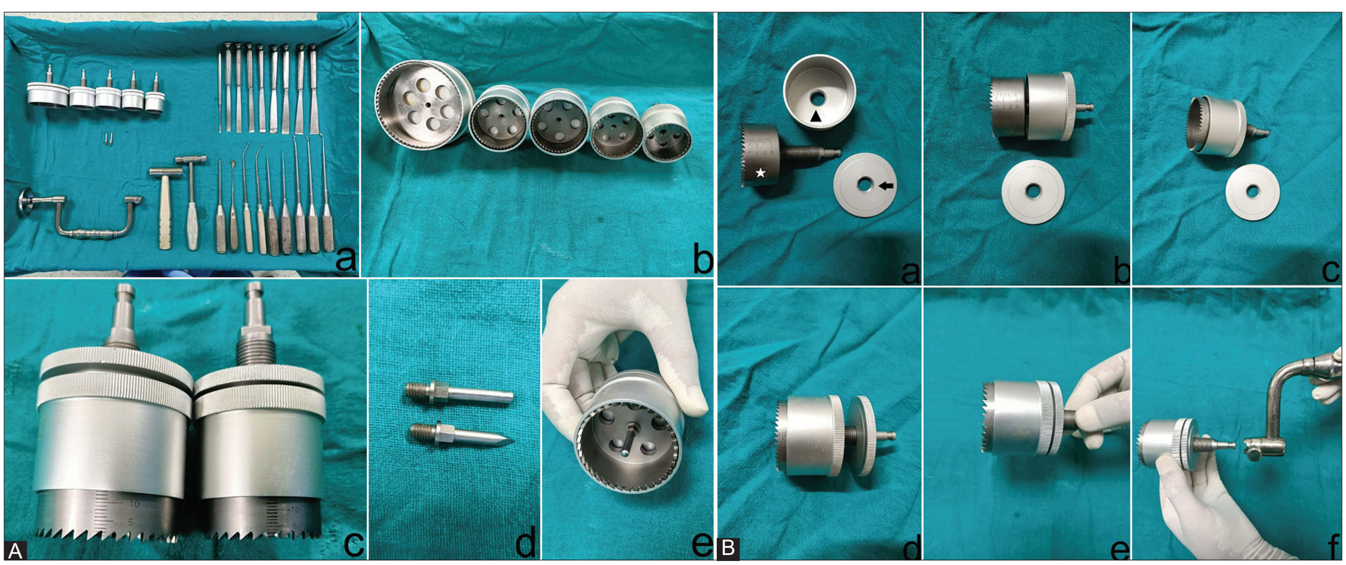

Figure 5: (A). The trephine craniotomy instrument set. The trepan, osteotomes, mallet, Hudson brace handle, and dissectors (a), various sizes of trepan (b), trepan with graduations over it (c), the centering drill, sharp, and blunt (d), and blunt pin *in situ* (e). (B). Assembling the trepan. (a) Parts of trepan showing high-speed cutting blade (star), dural guard (triangle), and fixator (arrow). Dural guard and fixator successively assembled and being mounted on Hudson brace handle (b-f).

speed cutting blade with graduated scale over it. Rotation of the outer dura guard adjusts the inner jaws. Rotate the dura guard and set it to minimum thickness calculated in step one using the graduation marks present over it. Now, the trephine can be tightened at this level. The center of the cylinder fits the retractable centring drill which acts as the stabilizer for the trephine. This pin has to be placed at the beginning which helps anchor the trephine and prevents its slippage. Now, the trephine bit is fixed to the Hudson brace handle. The instrument is now ready for use. Once few rotations have been made and the cutting blade has grooved out the bone, the retractable centring drill has to be replaced with a blunt centring drill. It is removed before the inner table is breached to prevent injury to the underlying dura mater [Figure 5].

Operative technique

For EDH

The cases of EDH are relatively easier with a trephine. The site of EDH is identified according to the CT scan. The size of craniotomy has to be assessed preoperatively and the appropriate size of trephine should be selected. In cases of EDH, dura is already separated from the bone and the space occupied by the hematoma. The circular trephine jaws length can be adjusted with rotation of the instrument. The length of cutting blade is fixed as per bone thickness measured in the CT scan to prevent injury to the dura. Once the bone flap is elevated, rest of the surgery is carried in a standard way of EDH evacuation.

Craniotomy over different parts of the skull

The craniotomy can be made easily over all the parts of the skull with few exceptions as discussed later. In FST craniotomy, we adjust the trephine by tilting it toward the frontal side. It is because the temporal bone is thinner compared to the frontal bone. The sphenoidal area, however, remains only partially accessible to the trephine. Once frontal and temporal bones are cut by the trephine, the sphenoidal area is gently cut using chisel and mallet and the bone flap is elevated. The placement of a burr hole over the sphenoidal ridge helps in separating dura over sphenoid and adjacent frontal and temporal regions [Figure 6]. In cases where the bone flap is not getting cut from any of the sides, a burr hole may be placed midway of the uncut margin. Using Kerrison bone punch, the remaining part of the bone may be cut on either side of the burr hole. Bone rongeurs can be used where additional sphenoidal ridge removal is desired. The powered craniotome also fails to cut the sphenoidal ridge area during pterional craniotomy and has to be either ronguered or drilled. However, ideal pterional craniotomy may not be made using a trepan. In cases of gliomas and meningioma which do not require bone removal flush with the supraorbital ridge and sphenoidal ridge, only those selected cases can be done with a trepan. For cases of posterior fossa EDH, the trephine is used depending on the dimensions of hematoma.

In cases where superior sagittal sinus (SSS) exposure is required, for example, parasagittal meningioma, the author makes two or more burr holes over the midline for the ease of dura separation and preventing sinus injury. After the placement of burr holes, surgical (oxidized cellulose) along with cottonoids was placed in the midline from both the ends to separate the sinus and displace it inferiorly rendering trepanation safe. Additional exposure of small part of the bone around the circular edges near SSS may be achieved using Kerrison punches.

For SDH

The chronic SDH may be evacuated using burr hole or twist drill trephination. However, in cases of recurrent CSDH with

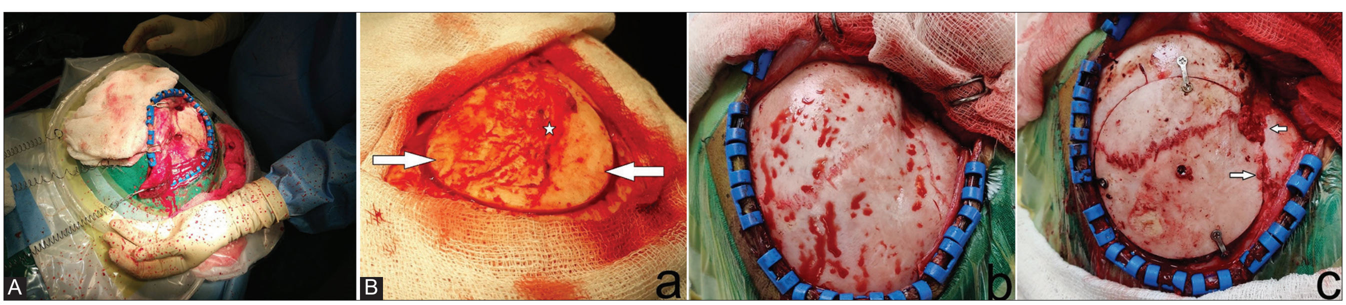

Figure 6: (A). The operative field during Gigli saw craniotomy. Extensive aerosol production is quite obvious. The settled heavier particles seen over surgeon and assistants' gown and surrounding areas. The saw wire carries fine droplets of blood and bone dust with itself which keeps spreading with every cutting movement. The image is taken when craniotomy is not even completed. The field was much worse than the presented image. (B). Intraoperative image showing frontal (left arrow) and temporal bone (right arrow) with temporalis reflected. The contours of both bones are not favorable for trepanation. The superior temporal line (star) forms an angulation between frontal and temporal region. However, by changing the working axis of the instrument, trepanation is still feasible (a), sphenoidal ridge area which is inaccessible to jaws of trephine because of its curvature (b), to overcome the inaccessibility of frontosphenotemporal area, the author makes burr hole over sphenoidal ridge covered with bone dust (left arrow). This burr hole was used for dural separation and acted as anchor site for osteotome in making posteroinferior temporal cut (right arrow) which could not be made using trepan (c).

thick membranes, trepanation may be done. For acute SDH, the procedure of trepanation is slightly different compared to EDH. The preoperative bone dura separation by hematoma and hence dura protection in EDH does not favor SDH. For cases of SDH, the technique is slightly modified. The large size trephine is usually required in acute SDH. As dura may be tense in acute SDH, trephine has used to be used precisely. The craniotomy is carried out slowly when the inner table is reached. At this juncture, the surgeon should look for complete thickness bone cut by close inspection of the margins at depth. If at few areas, bone is not grooved till the inner table, osteotome with mallet may be used to complete the craniotomy. The bone flap can be lifted gently using Penfield No.1 dissector and Pennybacker periosteal elevator.

CLINICAL CASE DISCUSSIONS

Case 1 (EDH)

A 12-year-old male presented with a history of trauma (fall from bike) followed by transient loss of consciousness. He complained of headache and one episode of seizure. On examination, GCS was E3V4M6 with drowsiness. NCCT head revealed right frontal EDH crossing midline and extending toward left along with contusion over the posterior aspect of EDH. The cause of the seizure was ascribable to parenchymal compression and contusion. Because of drowsiness, seizure, and compression over the brain parenchyma, surgical evacuation of EDH was planned. The patient was rushed to the emergency OR and a frontal craniotomy was made using a trepan [Figure 1]. There was a large EDH that extended beyond the margins of craniotomy. EDH was evacuated well. Multiple peripheral tenting sutures were taken and bone was fixed using sutures. Pericranial ends at incision site were approximated and the skin closed. The bone flap was removed easily with the help of trepanation. Furthermore, the operative field remained clean during surgery. The patient was extubated and his postoperative period was uneventful and recovered well. The importance of trepan was realized intraoperatively for its ease of use in the frontal region and minimal time taken for craniotomy.

Case 2 (SDH)

A 50-year-old male with drunken driving suffered a road traffic accident. He presented with GCS of E2V2M5. The pupils were constricted bilaterally and reacting to light. He also had right-sided weakness. He was immediately intubated and his vitals were stabilized. NCCT revealed left frontotemporoparietal acute SDH with mass effect. The NCCT had no underlying contusion, so a plan for trepanation with the largest trepan (3 inches) was made. The contusions are likely to increase later and cause edema worsening the mass effect. The size of craniotomy using a trepan may be inadequate in such cases. Hence, cases of SDH with no underlying contusions underwent trepanation. The trepanation was done with constant change in the long axis of the instrument for both anteroposterior direction and the temporal side of the bone. Dura was intact and tense with underlying SDH [Figure 2]. After SDH evacuation, the brain was found lax. The patient was ventilated electively for 24 h and then extubated. The patient's GCS improved to E4V5M6 on day 3 and was discharged later with no neurological deficits.

Case 3 (Subarachnoid hemorrhage [SAH] with ruptured aneurysm)

The trepan has been found useful in cases of aneurysms also. This was demonstrated by the authors in a case of M3 MCA aneurysm with intracerebral hemorrhage (ICH). An 8-year-old child presented with sudden onset of severe headache followed by vomiting and fall. On presentation, he was conscious and had GCS of E4V5M6. He also had left hemiparesis. NCCT brain revealed SAH with ICH in the right posterior frontal lobe. CT angiography showed an M3 MCA aneurysm [Figure 4]. The child underwent craniotomy using a trepan and clipping of the aneurysm. The hematoma was also evacuated and the brain was found lax at closure. Trepanation in such cases is difficult; however, with slight modification, the same can be achieved. The authors, however, do not advise trepanation in cases where proximal Sylvian fissure dissection is a must. In those cases, pterional craniotomy is preferred.

Case 4 (Glioma)

A 60-year-old female with a history of headache and dizziness for 1 month was evaluated. She also had a history of nausea and vomiting early morning for 1 week. On examination, she had mild hemiparesis of the left side along with inferior quadrant field defects. Her CT showed a hypointense lesion in the right parietotemporal region with perilesional edema. The MRI was suggestive of space-occupying lesion which was hypo on T1 and hyper on T2 sequence with heterogeneous enhancement on contrast. The findings were consistent with high-grade glioma [Figure 3]. She underwent craniotomy using trepanation with excision of the tumor. The authors could achieve trepanation at a fast pace. This helps to alleviate surgeons' fatigue in cases of neuro-oncology which can be of prolonged duration and they focus better on the intracranial pathology. The authors carried out trepanation in five cases of glioma. The trepanation can be performed in large gliomas also as they are intra axial in nature and large size craniotomy may not be required for their excision. It is pertinent to note that authors have been doing trepanation in trauma cases for more than a decade. This practice helped authors to use this technique in various other cases during the pandemic.

Advantages of trepan

The bone loss in trepanation is very minimal compared to craniotomy made using multiple burr holes. Hence, the cosmetic outcome is better. Less plates and screws are required for bone flap fixation. Burr hole covers are not needed at all. It also carries economical advantage as pneumatic or electric drills are heavily expensive. The time taken for craniotomy is significantly lesser compared to powered craniotomies or Gigli saw craniotomies. The time component is truly phenomenal as it curtails the duration of overall surgery and risk of exposure to all the HCWs of OR. The shorter trepanation time compared to other craniotomy modalities can have impact on overall prognosis of patients. The transmission of aerosol can further be minimized if trephine is made slowly. This ensures that the bone dust and blood remain confined to the craniotomy margins. It is a versatile instrument as the same instrument can be used in both pediatric and adult patients.

Limitations of trepan

The trepanation has its own set of limitations. There are various neurosurgical pathologies where it fails to carve out appropriate craniotomy. This is seen in areas that demand sinus exposure, for example, retromastoid craniotomy where both transverse and sigmoid sinus should be exposed. The ideal pterional craniotomy may not be made with trepan as it is circular. In cases that require removal of midline bone over the SSS, trepan carries the risk of sinus injury, for example, bifrontal craniotomy approach in cases of craniopharyngioma, anterior skull base meningiomas, CSF rhinorrhea repair with extensive skull base defect, and falcine meningioma. However, the same can be prevented by cutting the bones more on either side of the midline and gently cutting the midline using a small chisel and mallet. Alternatively, two burr holes may also be made at proximal and distal ends of the craniotomy margin over the midline. The dura and eventually sinus then can be easily separated and prevented from injury. The trepanation also carries the risk of injury to the dura mater, cortex, and injury to cortical vessels.

Kushner *et al.*[8] found up to 14% trepanations over the midline in Peru in different timelines. This suggests that trepanations were done over midline with crude instruments thousands of years ago. This is a significant finding which propels us to use it today.

The complications can be significantly controlled with regular practice. The art of turning and changing the axis of the trepan ensures uniform and symmetrical grooves over the bone. The use of additional burr holes will avert injury to dura mater and sinuses.

Proposed COVID-19 craniotomy guidelines

1. The author advocates trephine craniotomy wherever possible. Almost all the traumatic head injury cases can be operated using trepan.
2. In cases where trepanation is not possible, Gigli saw craniotomy should be the next preferred technique.
3. The power drill system may be used in drilling anterior clinoid, Kawase triangle, internal auditory canal, etc. However, PD should be avoided or may be used a bare minimum.

Merits of the study

The first study was to describe the technique of trepanation in a detailed manner and also evaluated its benefits in COVID crisis. The craniotomy time by various instruments was studied which has never been reported in the literature.

Limitation of the study

The study lacks the objective evaluation of the aerosol particles suspended in the air.

CONCLUSION

A stratagem of innovations and strict adherence to set guidelines is the only resuscitative methods in the existing crisis. The practice of the art of trepanation among residents and young neurosurgeons should be promoted. The ancient trepan continues to show its usefulness in modern-day neurosurgery. The trepanation can have a significant role in mitigating the risk of aerosol transmission in neurosurgical OR. The technique should be the preferred method of craniotomy during the COVID pandemic.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Conflicts of interest

The authors declare no competing financial interest.

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