MDCT Evaluation of Post-Operative Cranium: Spectrum of Normal Findings & Complications

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ABSTRACT

Imaging plays an essential role in the evaluation of patients after cranial surgery. Postoperative infection and hemorrhage are common complications after cranial surgeries. Life-threatening complications (like tension pneumocephalus and paradoxical herniation) must be identified rapidly at imaging to secure a favorable prognosis. This cross-sectional study included 250 patients who underwent variant neurosurgical operations and were imaged for the developed postoperative complications using Computed Tomography (CT), Magnetic Resonance Imaging (MRI) with and without contrast. We reviewed the common normal and abnormal findings in post-operative neurosurgical patients. The expected postoperative CT and MRI appearances of these procedures are discussed, followed by complications. These include hemorrhage, tension pneumocephalus, wound/soft tissue infection, bone flap infection and extradural abscesses. Complications specifically related to craniectomies include extracranial herniation, external brain tamponade, paradoxical herniation, and trephine syndrome. In our study 165 male; 58 % and 85 female; 42 % were included; age range (6months-69 years), mean age 34.7 ± 2.9 years. 130 patients underwent craniotomy, infection (23%) was the most dominant complication followed by intracranial hemorrhage (19%). So to conclude; radiologist must know how to recognize postoperative complications and differentiate them from expected normal findings because an early and accurate diagnosis is important for proper postoperative care. Computed tomography is fast, cost effective, and easily accessible for first-line imaging. Magnetic resonance imaging has higher sensitivity for detecting postoperative infection and ischemia.

INTRODUCTION

Imaging has a crucial role in evaluating those who underwent cranial surgery. Postoperative infection and haemorrhage are common (Xu et al, 2016). To ensure a more effective prognosis, urgent diverse complications including tension pneumocephalus and paradoxical herniation, that mandate urgent interference, must be identified immediately and informed to the surgeon, here comes the valuable imaging role at such circumstances (Sinclair and Scoffings, 2010).

To analyze images of postoperative state, a wide range of knowledge for normal anatomy of the cranium, as well as the deployed technical aspects of surgery, including burr holes, craniotomy, craniectomy and cranioplasty is required. CT owes many fruitful advantages like being fast, rapid accessibility, compatibility with monitoring devices and
implants, as well as relatively costless, compared to other imaging devices (Guilabert et al., 2013; Akins and Guppy, 2008).

However, CT is less sensitive than magnetic resonance (MR) imaging in the delineation of serious complications such as infection and ischemia, though MRI is contraindicated in cases of non-compatible clips or implants (Chauhan et al., 2017; Gupta and Gelb, 2008).

The goal of this work is to evaluate the role of imaging in the detection of postoperative cranium common findings and complications.

**METHODS**

**Study design and population**

Two hundred fifty patients were included in this prospective cross-sectional study. Their age ranged as six months to 69 years old with a mean age of 35.5 years. They were referred from the neurosurgery department to the department of diagnostic radiology during the period from February 2017 to February 2020. Before the beginning of the study, a local institutional review board (IRB) approval and informed consents from all patients or the parents were applied.

Both sex patients were included, as well as those who did cranial operation or intervention, patients with burr hole, craniotomy or craniectomy. Pregnant females or those unwilling to complete the study were excluded. Patients with claustrophobia for MRI or those with non-compatible implants or clips that interfere with performing MRI were excluded. All patients were subjected to the following:

**Brief history taking**

1. Personal history (name, age, occupation)
2. Present history (complaints): headache, hemiparesis, hemiplegia numbness, seizures, tremors, fever and coma.
3. Past history type of neurosurgical procedure, surgery indication (tumour, vascular disease, trauma or others) and date of surgery.
4. General and neurological examination of the patients: (Carried out by referring clinician).

**Scan protocol and parameters**

Patients underwent MDCT of the brain in axial plane starting from the skull base without gantry tilt to cover all skull up to the vertex using Philips 128™ ingenuity CT (Medical Systems, Nederland) with the following parameters: Detector collimation 16×2 mm, tube voltage 100 kV and tube current 150–250 mA. Pitch of 0.9, rotation time 0.7 s, reconstruction slice width 0.6 mm and increment 0.5 mm. No contrast material was applied unless needed, such as if suspected inflammatory process. CT angiography of the brain & neck vessels was done if suspected vascular injury with the bolus of iopromide (Ultravist 370, Bayer Health Care) was injected into an antecubital vein at a flow rate of 4.5 ml/s. The dose of iopromide was calculated according to the patient body weight (1.5 ml/kg). Peak enhancement in the aortic root was automatically detected with a threshold of 150 Hounsfield Unit using bolus tracking method. The procedure was done within a single breath-hold (from 10 to 15 s). MRI examination was done using a 1.5- Tesla superconducting magnet (Achieva, Philips Medical System, Best, Netherlands), using torso head coil. Both CT & MRI exams were performed with the patients lie in a supine position with the head first. The field of view (FOV) extends from the level of the aortic arch up to the skull vault.

**Image analysis**

Patient data were removed automatically from the DICOM meta-data by Image Inbox before image transfer. All CT, MR & CTA images were sent to an advanced workstation (Philips MR extended workspace, software version 2009). Coronal & sagittal reconstructed CT images by MPR was applied, MIP was used for CTA.

**Statistical Analysis**

The data analysis was performed using SPSS 20 (Chicago SPSS, SPSS Inc., Chicago, IL). Qualitative data were expressed as number and percent. Quantitative data were displayed as mean and SD. The complications were classified as tension pneumocephalus, infection (soft tissue infection, bone flap infection, empyemas or brain abscesses), haemorrhages (intraparenchymal, intraventricular and subdural or epidural hematomas), hydrocephalus, infarction and others. The frequency of each one was calculated. The rate of complications in all the 250 neurosurgical procedures was calculated according to the surgical indication and type of surgery.

**RESULTS**

The studied group included 165 males (58%) and 85 females (42%). The age range was six months to 69 years with a mean age of 34.7 years. The most dominant age group was 20-30 years old (22 %).
Table 1: Age and sex distribution among the 250 studied patients

| Age group | Number | % | Male | % | Female | % |
|-----------|--------|---|------|---|--------|---|
| 0-10      | 20     | 8 | 10   | 4 | 10     | 4 |
| 10-20     | 50     | 20| 40   | 20| 10     | 4 |
| 20-30     | 55     | 22| 30   | 15| 25     | 10|
| 30-40     | 45     | 18| 25   | 10| 20     | 8 |
| 40-50     | 30     | 12| 15   | 6 | 15     | 6 |
| 50-60     | 35     | 14| 15   | 6 | 20     | 8 |
| >60       | 15     | 6 | 10   | 4 | 5      | 2 |
| Total     | 250    | 100| 165  | 58| 85     | 42|

Table 2: Type of surgery done for patients included in the study

| Type of surgery | Number | % |
|-----------------|--------|---|
| Urgent          | 155    | 62 % |
| Programmed      | 95     | 38 % |

Table 3: Post-operative clinical presentation of patients included in the study

| Symptoms and signs                              | Number | % |
|-------------------------------------------------|--------|---|
| Head swelling                                   | 40     | 16 |
| Fever                                           | 75     | 30 |
| Headache /hemiparesis /hemiplegia               | 60     | 24 |
| Weakness /coma                                  | 25     | 10 |
| Coma                                            | 40     | 16 |
| Sunken flap                                     | 10     | 4  |

Table 4: Techniques used in the surgeries

| Burh hole | Craniotomy | Craniectomy |
|-----------|------------|-------------|
| Number    | 10         | 130         | 110         |
| %         | 4          | 52          | 44          |

Table 5: Normal post-operative findings and complications

| Normal post-operative findings | No. of cases | % |
|--------------------------------|--------------|---|
| Normal postoperative enhancement | 10           | 4% |
| Normal Postoperative Pneumocephalus | 35          | 14% |
| Normal Postoperative Bleeding    | 25           | 10% |
| Abnormal post-operative findings | 180         | 72% |
| Tension pneumocephalus           | 15           | 6% |
| Infection                        | 65           | 26% |
| Infarction                       | 20           | 8% |
| Postoperative intracranial hemorrhage | 40    | 16% |
| Extracranial herniation          | 25           | 10% |
| External brain tamponade         | 5            | 2% |
| Paradoxical herniation           | 5            | 2% |
| Trephine syndrome                | 5            | 2% |
Table 6: Distribution of hematomas in patients included in the study

| Distribution of hematomas          | No. of cases | %   |
|-----------------------------------|--------------|-----|
| Subdural hematoma                 | 14           | 35% |
| Epidural hematoma                 | 4            | 10% |
| Intraparenchymal hematoma         | 8            | 20% |
| Intraventricular hematoma         | 2            | 5%  |
| Subgaleal hematoma                | 12           | 30% |

Table 7: Distribution of infections in patients included in the study

| Distribution of infections          | No. of cases | %   |
|------------------------------------|--------------|-----|
| Subdural empyema                   | 10           | 15% |
| Epidural abscess                   | 15           | 23% |
| Intraparenchymal abscess           | 15           | 23% |
| Ventriculitis and ventricular abscess | 5         | 9%  |
| Bone flap osteomyelitis            | 20           | 30% |

Table 8: Complications detected in craniotomy patients included in the study

| Complications                                | No. of cases | %   |
|----------------------------------------------|--------------|-----|
| Tension pneumocephalus                       | 5            | 4%  |
| Infection                                    | 30           | 23% |
| Infarction                                   | 10           | 8%  |
| Postoperative intracranial hemorrhage        | 25           | 19% |
| Extracranial herniation                      | 10           | 8%  |
| External brain tamponade                     | 0            | 0%  |
| Paradoxxial herniation                       | 0            | 0%  |
| Trephine syndrome                            | 0            | 0%  |

Table 9: Complications detected in craniectomy patients included in the study

| Complications                                | No. of cases | %   |
|----------------------------------------------|--------------|-----|
| Tension pneumocephalus                       | 10           | 9%  |
| Infection                                    | 35           | 32% |
| Infarction                                   | 10           | 9%  |
| Postoperative intracranial hemorrhage        | 10           | 9%  |
| Extra cranial herniation                     | 15           | 14% |
| External brain tamponade                     | 5            | 5%  |
| Paradoxxial herniation                       | 5            | 5%  |
| Trephine syndrome                            | 5            | 5%  |

(Regarding the type of surgery done for patients included in the study, we found that urgent surgeries were done for 155 (62%) of patients included in the study and programmed surgeries were done for 95 (38%) of patients included in the study (Table 2). Fever was the most common clinical post-operative presentation in the patients included in our study that was found in 75 (30%) patients, followed by headache in 60 (24%) patients then coma in 40 (16%) patients (Table 3).)

Regarding the techniques used in the surgeries in the studied group, a craniotomy was done in 130 patients (52%), craniectomy was done in 110 patients (44%), and a burr hole was made in 10 patients (4%) (Table 4). Normal (70 = 28%) & abnormal (180 = 74%) postoperative findings are summarized at Table 5 with the most frequent normal post-operative finding was pneumocephalus (35=14%) while the most frequent abnormal post-operative infection (65=26%). Regarding the distri-
bution of hematomas in our studied group we found subdural hematomas in 14 (35%) patients, epidural hematomas in 4 (10%) patients, intraparenchymal hematomas in 8 (20%) patients, intraventricular hematomas in 2 (5%) patient and Subgaleal hematomas 12 (30%) patients (Table 6).

Regarding the distribution of infections in our studied group we found subdural empyema in 10 (15%) patients, epidural abscess in 15 (23%) patients, intraparenchymal abscesses in 15 (23%) patients, ventriculitis and intraventricular abscess in 5 (9%) patient and bone flap osteomyelitis in 20 (30%) patients (Table 7). The most frequent complication detected in craniotomy & craniectomy patients included in the study was the infection that found in 30 (23 %) & 35 (32 %) cases respectively Table 8 & Table 9. At the same time, the only complications detected in burr hole patients included in the study was the intracranial haemorrhage that occurred at 5 cases only (50 %).

Cases

Case (1)
35 years old female patient with operated intraparenchymal hematoma, presented by LT parietal swelling and RT sided weakness (Figure 1).

Case (2)
46 years old male trauma patient underwent an operation for subdural hematoma evacuation, then five months later, he presented with fever pain and swelling at the operative site (Figure 2).

Case (3)
3 years old female patient with operated intraparenchymal hematoma since eight months and comatose since the operation, now she developed a fever (Figure 3).

Case (4)
40 years old male patient with operated right subdural hematoma presented with headache and head swelling at the operative site (Figure 4).

DISCUSSION

Dialy surgical practice includes those who need cranial neurosurgical procedures, deploying a wide range of techniques, especially to treat intracranial disorders (Desai, 2016; Delgado-López et al., 2009). The radiologist must know how to recognize postoperative complications and differentiate them from expected normal findings because early and accurate diagnosis is vital for proper postoperative care (Farrell et al., 2008). Therefore to analyze images of postoperative state, a wide range of knowledge for normal anatomy of the cranium, as well as the deployed technical aspects of surgery, including burr holes, craniotomy, craniectomy and cranioplasty is required—also the underlying pathology and the clinical status of the patient. Clinical, surgical and radiologic correlation is essential (Hutchinson et al., 2007; Heit et al., 2017).

In the early postoperative period, CT owes many fruitful advantages like being fast, rapid accessibility, compatibility with monitoring devices and implants, as well as relatively costless, compared to other imaging devices (Guilabert et al., 2013; Akins and Guppy, 2008). However, CT is less sensitive than magnetic resonance (MR) imaging in the delineation of serious complications such as infection and ischemia, though MRI is contraindicated in cases of non-compatible clips or implants (Nowinski, 2011). CT is useful to evaluate complications such as haemorrhage, brain oedema, tension pneumocephalus, brain herniation and infection (contrast-enhanced CT) (Pandey et al., 2008; Shi et al., 2017).

Our study included 250 patients. They were 165 males and 85 females; their ages were ranged from 6 months to 69 years with the mean age 34.7 years. Postoperative complications were more common in patients who underwent urgent surgeries (62 %) than patients who underwent programmed surgeries (38 %), these results were in agreement with Shi et al. (2017) who found similar results.

The techniques used in the surgeries in our study, a craniotomy was done in 130 patients, craniectomy was done in 110 patients, and a burr hole was made in 10 patients.

Regarding the postoperative clinical presentation in patients included in our study we found that fever was the most common clinical presentation found in 75 (30%) patients, followed by headache in 60 (24%) patients then coma in 40 (16%) patients.

Regarding the expected normal postoperative findings we found that customarily expected postoperative pneumocephalus was most common expected postoperative finding was found in 35 (14%) patients followed by normally expected postoperative bleeding which was found in 25 (10%) patients, then normally expected postoperative enhancement which was found in 10 (4%) patients.

Regarding the complications detected in patients included in our study we found that infection is the most common complication found in 65 (26%) patients followed by intracranial haemorrhage found in 40 (16%) patients, then extracranial brain herniation was found in 25(10%) patients.
Figure 1: (A): 3D reformatted CT image of the skull (B): CT brain with coronal reconstruction (C&D): Axial CT brain CT shows burr hole with LT parietal pneumocephalus at site of evacuated hematoma, also there is LT parietal hematoma

Figure 2: A): Preoperative CT revealed RT subdural hematoma and subgaleal hematomas (B&C): Immediate postoperative CT revealed demonstrates a normal appearance of craniotomy flap (D, E, F, G&H): Axial CT brain done 5 months postoperative revealed Osteomyelitis of craniotomy flap
and infarction was found in 20 (8%) and then; tension pneumocephalus was found in 15 (6%) patients then external brain tamponade, paradoxical herniation and trephine syndrome; each was found in 5 (2%) patient.

In the study done by Seifman et al. (2011), they found that extracranial herniation is the most common complication found in 18/90 (20%) patients followed by hygromas were found in 16/90 (18%) patients haemorrhage in 15/90 (17%) patients then infarctions were found in 14 (16%) patients. Infection was found in 12/90 (13%) patients 4/12 (34%) patients then hydrocephalus was found in 10/90 (11%) patients and tension pneumocephalus in 4/90 (4%) patients.

Regarding the distribution of hematomas in our studied group, we found subdural hematomas in 14/40 (35%) patients, subgaleal hematomas 12 (30%) patients, intraparenchymal hematomas in 8/40 (20%), epidural hematomas in 4/40 (10%) patients & intraventricular hematomas in 2/40 (5%) patient. In the study done by Guilabert et al. (2013), they found 15/90 (17%) of cases with different types of haemorrhage, 5/15 (33%) subdural hematoma, 4/15 (27%) subgaleal hematoma, 4/15 (27%) intraparenchymal haemorrhage and 2/15 (13%) others haemorrhages (intraventricular haemorrhage).

As a rule of thumb, the body provokes an inflammatory response after any surgical procedure, including the traumatized tissues, this response is delineated as contrast enhancement on imaging. Postcraniotomy contrast-enhanced studies demonstrate enhancement of this defect, which in some cases is limited to the margins (Ho and McAdory, 2019). Regarding the distribution of infections in our studied group, we found that the rate of infection was 65/250 (26%) found subdural empyema in 10/65 (15%) patients, epidural abscess in 15/65 (23%) patients, intraparenchymal abscesses in 15/65 (23%) patients, ventriculitis and intraven-
tricular abscess in 5/65 (9%) patient and bone flap osteomyelitis in 20/65 (30%) patients.

In the study done by Guilabert et al. (2013), they found that the rate of infection was 12/90 (13%): 4/12 (34%) were subdural empyemas. There were 3/12 (25%) soft tissue or subgaleal infections. 3/12 (25%) were CSF infections, with ventriculitis or meningitis. 1/12 (8%) were intraparenchymal abscesses. There was 1/12 (8%) bone flap infection in the context of a cranioplasty. Regarding the complications detected in craniotomy patients included in our study we found that infection was the most common complication found in 20 (23%) patients followed by intracranial hemorrhage found in 15 (14%) patients then infarction and extra cranial brain herniation each found in 10 (9%) patients and tension pneumocephalus found in 5 (4%) patients.

Regarding the complications detected in craniectomy patients included in our study we found that infection is the most common complication found in 35 (32%) patients followed by extra cranial brain herniation found in 15 (14%) patients, then tension pneumocephalus, intracranial hemorrhage and infarction; each was found in 10 (9%) patients then external brain tamponade, paradoxical herniation and trephine syndrome; each was found in 5 (5%) patients. However, Chughtai et al. (2019) found that extracranial brain herniation is the most common complication of the craniectomy. Regarding the complications detected in burr hole patients included in our study, we found postoperative intracranial haemorrhage in 2 (4%) patient.

CONCLUSION

Imaging is essential in the routine postoperative follow-up of these patients. The radiologist must know how to recognize postoperative complications and differentiate them from expected normal findings because early and accurate diagnosis is important for proper postoperative care.

Declarations

Consent for publication

All patients included in this research gave written informed consent to publish the data contained within this study.

Conflict of interest

The authors declare that they have no conflict of interest for this study.

Funding Support

The authors declare that they have no funding sup-
port for this study.

Authors contributions
IM participated in the sequence alignment, RM carried out the study concept and design, participated in the sequence alignment, drafted the manuscript and carried out the process of literature search. MM and AA also participated in the sequence alignment and participated in the design of the study. HA performed the statistical analysis. All authors read and approved the final manuscript.

List of Abbreviations
IRB (Institutional review board), FOV: Field of view, MDCT: multidetector CT.

REFERENCES
Akins, P. T., Guppy, K. H. 2008. Sinking Skin Flaps, Paradoxical Herniation, and External Brain Tamponade: A Review of Decompressive Craniectomy Management. Neurocritical Care, 9(2):269–276.
Chauhan, N. S., Banday, I. A., Morey, P., Deshmukh, A. 2017. External brain tamponade: a rare complication of decompressive craniectomy. Internal and Emergency Medicine, 12(1):117–118.
Chughtai, K. A., Nemer, O. P., Kessler, A. T., Bhatt, A. A. 2019. Post-operative complications of craniotomy and craniectomy. Emergency Radiology, 26(1):99–107.
Delgado-López, P. D., Martín-Velasco, V., Castilla-Diez, J. M., Galacho-Harriero, A. M., Rodríguez-Salazar, A. 2009. Preservation of bone flap after craniotomy infection. Neurocirugía, 20(2):124–131.
Desai, V. R. 2016. Incidence of intracranial hemorrhage after acrinal operation. Cureus, 8(5).
Farrell, C. J., Hoh, B. L., Pisculli, M. L., Henson, J. W., Barker, F. G., Curry, W. T. 2008. Limitations of diffusion-weighted imaging in the diagnosis of postoperative infections. Neurosurgery, 62(3):577–583.
Guilabert, H., and I M Amosa, H. I., Capilla, E. 2013. The postoperative cranium, normal findings and complications. EPOS-C-1330 (European Society of Radiology).
Gupta, A. K., Gelb, A. W. 2008. Essentials of neuroanesthesia and neurointensive care. pages 87–97. Phila–delphia, Pa: Saunders.
Heit, J. J., Ivy, M., Wintermark, M. 2017. Imaging of Intracranial Hemorrhage. Journal of Stroke, 19(1):11–27.
Ho, C. L., McAdory, L. 2019. Postoperative Imaging of Complications Following Cranial Implants. Journal of the Belgian Society of Radiology, 103(1):1–5.
Hutchinson, P., Timofeev, I., Kirkpatrick, P. 2007. Surgery for brain edema. Neurosurgical Focus, 22(5):1–9.
Nowinski, W. 2011. Introduction to Brain Anatomy. In K, M., et al., editors, Biomechanics of the Brain, volume 1, pages 5–40, New York. Springer.
Pandey, P., Madhugiri, V. S., Sattur, M. G., B. I. D. 2008. Remote supratentorial extradural hematoma following posterior fossa surgery. Child’s Nervous System, 24(7):851–854.
Seifman, M. A., Lewis, P. M., Rosenfeld, J. V., Hwang, P. Y. K. 2011. Postoperative intracranial hemorrhage: a review. Neurosurgical Review, 34(4):393–407.
Shi, Z. H., Xu, M., Wang, Y. Z., Luo, X. Y., Chen, G. Q., Wang, X., Wang, T., Tang, M. Z., Zhou, J. X. 2017. Post-craniotomy intracranial infection in patients with brain tumors: a retrospective analysis of 5723 consecutive patients. British Journal of Neurosurgery, 31(1):5–9.
Sinclair, A. G., Scofings, D. J. 2010. Imaging of the Post-operative Cranium. Radiographics, 30(2):461–482.
Xu, H., Shi, H., Wu, H. 2016. Normal anatomy of brain. CT and MR imaging of the whole body, 1(8):133–57.