A RETROSPECTIVE REVIEW OF FINDINGS ON POST-OPERATIVE CRANIAL COMPUTED TOMOGRAPHY AND MAGNETIC RESONANCE IMAGING SCANS AT KENYATTA NATIONAL HOSPITAL

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Declaration

I declare that the work contained herein is my original idea and has not been presented at any other place in Kenya to the best of my knowledge.

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Dedication

To my wife Barbara, for her practical and moral support

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List of abbreviations

ACR- American College of Radiology

CSF- Cerebrospinal fluid

CSH-Chronic subdural hematoma

CT-Computed tomography

DVT-Deep venous thrombosis

ERC- Ethical review committee

FLAIR- Fluid attenuation Inversion Recovery (MRI sequence)

ICP- Intracranial pressure

ICU-Intensive care unit

MRI-Magnetic resonance imaging

KNH-Kenyatta National Hospital

PACS- Picture archiving and communication system

PET- Positron emission tomography

RANO-Response assessment in neuro-oncology (working group)

SAS-Statistical analysis system

SPECT- Single photon emission computed tomography

T1W - T1 weighted image

T2W -T2 weighted image

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Abstract

Background: Post-operative cranial scans are not necessarily obtained in all patients following neurosurgical procedures. The scans may also be obtained after varying periods of time. Appropriate utilization of the scans should lead to increased identification of the critical post-surgical findings that would influence subsequent patient management. This study was set to determine the situations in which postoperative imaging would be most beneficial in neurosurgical patients at Kenyatta National Hospital (KNH)

Methods: This was a retrospective review of patients who underwent cranial surgery at KNH between June 2011 and May 2013 and followed-up for a maximum period of 6 months. Medical records were evaluated to reveal the clinical characteristics of the patients, presence and timing of post-operative scans, imaging findings and subsequent surgical management of the patients. The data was manually collected and thereafter analyzed using statistical computer software (SAS). The evaluation involved descriptive statistics, chi square statistics, Kaplan Meir curves and competing risk analysis. Results are presented in the form of frequency distributions and descriptive statistics.

Results: The study found that53 (18%) of the 298 patients reviewed had scans within a median time of 20 days after cranial surgery. Patients that were admitted in the hospital for between 30-90 days had the highest chance of getting a postoperative scan. Forty percent of the scans were ordered for routine follow up and the rest (60%) due to neurological derangement in the patient. Majority (36; 68%) of the post-operative scans had a positive finding. However, only 20 (38%) of the scans had findings that necessitated a subsequent surgical procedure. Furthermore, the findings that necessitated a subsequent surgical procedure were much more common among scans ordered due to neurological derangement as compared to scans ordered for routine post-operative follow-up (54% vs 14%, p=0.005). The chances of detecting a positive finding did not vary whether the scans were done within or after 30 days following surgery. Similarly, the post-operative time at which the scan was done (either <30, 30-60 or >60 days) did not influence the chances that the findings of the scan would necessitate subsequent surgical intervention.

Conclusions: The proportion of neurosurgical patients that gets post-operative scans at KNH is acceptable because it is comparable to the proportion of patients that is expected to have the postoperative complications that we need to detect and manage. Increasing the proportion of patients who get routine scans is unlikely to optimize the role of the scans in managing the postoperative patients. Instead, patients at a higher risk of developing postoperative complications should be identified and targeted for imaging. There is no particular post-operative period during which scans are collectively better at yielding findings of surgical importance, thus the appropriate time for imaging should be guided by the indication for imaging.

1.0 GENERAL INTRODUCTION

1.1 Background Information

Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) scans (here in thereafter referred to as post-operative scans) are radiological investigations which are currently readily available at Kenyatta National Hospital (KNH). These imaging modalities have been used to improve the healthcare services offered to neurosurgical patients seen at the facility. However, clinicians' preferences when requesting for post-operative scans for neurosurgical patients have not been documented and the utilization of these investigations has not been assessed. This study aims to characterize the use of post-operative CT and MRI scans with the aim of establishing how much they influence the post-operative management of neurosurgical patients at KNH.

Different neurosurgical conditions require a variety of surgical procedures to address them. These procedures include the creation of burr holes, insertion of CSF drainage shunts, craniotomy or craniectomy. The goals of imaging in the post-operative period are to assess early post- operative complications such as intracranial hemorrhage, to determine the amount of residual tumor or recurrent disease, and to determine delayed treatment complications like radiation necrosis [1].The need for imaging as well as the appropriate timing of the scans must be considered in order for the findings to optimally benefit the patients' clinical management. Depending on the indication(s), post-operative imaging of the cranium may be done after varying periods of time, and may be repeated several times. The timing of the imaging needs to capture the onset, the progress and/or resolution of the post-surgical events [2, 3].

The choice of imaging modality to use depends on, among other factors, its accuracy in answering the clinical question, safety to the patient and the cost of providing the service. Accurate interpretation of post-surgical imaging studies requires knowledge of the normal cranial anatomy, the indications of the various surgical techniques and their normal post-operative appearances; as well as the expected complications [4]. Apart from clinical relevance, the other important aspect of a post-operative scans is the cost-effectiveness of the additional investigations in resource poor settings.

For these reasons, the extent of utilization of the scans is likely to be contextualized to the need for post-operative imaging in any given patient [5]. Different factors will determine the appropriate candidate for imaging, the suitable imaging modality to be used, the correct timing of the imaging study as well as meaningful interpretation of the results.

Appropriately obtained scans should accurately observe the post-operative intracranial events and direct the prompt implementation of interventions when and where necessary. Post-operative radiological findings are critical in determining whether subsequent surgical procedure is necessary or conservative management will suffice.

This study aimed to highlight the utilization and impact of post-operative scans with a view to identify opportunities for improving neurosurgical care at KNH.

1.2 Study justification

Optimal use of radiological investigations denotes that all patients in whom they are indicated receive the investigations and subsequent results will be of clinical benefit to the patient. Currently, only a certain fraction of neurosurgical patients will have post-operative scans; this may potentially deny some diagnostic benefit to other eligible patients. On the other hand, indiscriminate imaging exposes patients to unwarranted radiation injury and also has a significant bearing on the costs of healthcare. This study sought to estimate the proportion of neurosurgical patients that underwent post-operative radiological investigations and the diagnostic and therapeutic benefit accrued from utilization of these imaging studies. This was done with a view to point out gaps that can be addressed to optimize the use of post-operative scans. To the best knowledge of the author, the study had not been previously conducted locally.

1.3 Research question

1. What is the pattern of findings of post-operative cranial imaging studies for patients who have undergone neurosurgical procedures at KNH?

2. How are the findings of cranial postoperative scans applied towards managing the neurosurgical patients?

1.4 Research Objectives

1.4.1 Main objective

To determine the pattern of findings on post-operative cranial scans obtained within 6 months of surgery, and they role they played in the management of the neurosurgical patients operated between June 2011 and May 2013 at Kenyatta National Hospital (KNH).

1.4.2 Specific objectives

1. To determine the proportion of neurosurgical patients who underwent post-operative cranial imaging studies within 6 months of surgery at among the 2011-2013 cohort at KNH.
2. To determine the indications for post-operative cranial imaging among the 2011-2013 cohort at KNH.
3. To determine the timing (scheduling) of post-operative cranial imaging among the 2011-2013 cohort at KNH.
4. To establish the pattern of radiological findings seen and correlate them to the timing of the post-operative imaging studies among the 2011-2013 cohort at KNH.

2.0 LITERATURE REVIEW

This section will introduce the imaging modalities used in this study, discuss the indications, timing (scheduling), and findings of post-operative imaging and then conclude with a summary.

2.2 The role of CT/MRI scans in post-operative cranial imaging

Computed tomography (CT) is the major imaging modality used to evaluate post-operative conditions. Its' cross sectional imaging capabilities provides a highly accurate representation of intracranial pathologies. CT scan findings have been shown to be an independent predictor of post-operative outcomes in certain disease conditions. CT is a suitable technique for comparing different sets of images because it is highly reproducible and allows for direct comparison of imaging findings. This becomes important when evaluating disease progression on current images while relating to the previous ones. Other advantages of CT include its speed of imaging, compatibility with monitoring devices for critically ill patients, and its lower costs in comparison to MRI [6, 7].

In the early post-operative period, non- contrast enhanced CT can detect complications such as hemorrhage, edema, tension pneumocephalus and brain herniation. Administration of contrast material is usually required whenever infection is suspected [4].

Compared to CT, Magnetic resonance imaging (MRI) has better soft tissue contrast making it more sensitive to various lesions. In the early post-operative period, MRI can accurately define the extent of tumor resection. MRI findings correlate well with overall patient survival. Contrast-enhanced MRI is currently the standard for the assessment of tumor progression. Its accuracy however, is affected by significant inter-observer variability, difficulty in interpretation, and poor specificity for radiation necrosis verses tumor progression. Although it is more sensitive than CT at evaluating intracranial infection and ischemia; its role in the early post-operative period is limited by the cost, availability and potentially non-compatible surgical implants or equipment [4, 8, and 9]. There is need for an imaging modality that can address these challenges.

2.3 Indications for post-operative imaging

Imaging guidelines are described as ‘a concept of good practice against which the needs of the individual patient are to be considered’ and ‘are not meant to provide a rigid constraint to clinical practice’. Referring clinicians and radiologists therefore have the opportunity and obligation to customize the choice and timing of imaging studies to the patient’s clinical condition. It is recommended that the ultimate decision regarding the appropriateness of any specific radiological examination must be made after considering all the factors relevant to the individual examination. In fact, it is not unusual to find a ‘disclaimer’ regarding strict adherence to a given imaging guideline. Generally, the basic indication for post-operative imaging would be the presence of neurological deterioration [5, 10, and 11].

The goals of imaging in the post-operative period are to assess for, early post- operative complications such as intracranial hemorrhage, amount of residual tumor or recurrent disease, and delayed treatment complications like radiation necrosis [1].

2.4 Appropriate timing (scheduling) of post-operative imaging

Accurate timing of post-operative imaging ensures that post-operative imaging coincides with the appearance of specific findings in different neurosurgical conditions some of which may require prompt intervention [3]. For example, acute post-operative intracranial hemorrhage may require imaging in the immediate post-operative period; less acute conditions such as infection will need imaging within a few days or weeks while long term concerns complications such as recurrence of tumors can be addressed over several months or years. However, in some situations, the ideal timing of post-operative studies is still regarded as a controversial issue and the final decision might also depend on the clinician’s preferences [12].

Studies aimed at establishing the optimal timing of post-operative imaging have produced mixed results. Routine post-operative imaging did not predict the probability of a subsequent operation in neurosurgical patients in USA in the year 2010. Additionally, in an attempt to establish the optimal time for obtaining images that will determine the effects of surgery in patients with various diagnoses, early post-operative scans were found unhelpful in predicting significant intracranial changes that evolve with time. Conversely, a separate study (that evaluated trauma patients only) seemed to find value in early or immediate post-surgical imaging. In this case, early imaging helped to prevent avoidable delays in treatment of new or recurrent findings [2, 13]. The challenge should then be to identify the patients that would benefit most from early post-operative imaging.

In the absence of acute neurological deterioration, some neurosurgical centers recommend imaging between the second and the seventh post-operative day, while other centers will allow the patient home and schedule a review within 8 weeks to determine the need for post-operative imaging [14, 15].

Chronic or persistent conditions usually require follow up using radiological examinations. There are situations where a single scan may remain inconclusive whereas comparing serial scans will greatly increase the confidence towards a given diagnosis. For example, serial post-operative imaging studies have been shown to be useful in distinguishing normal post-operative enhancement from residual tumor or infection [16]. This finding clearly justifies repeated imaging, but the requesting clinician needs to define the spacing of subsequent scans and an agreeable end point. In some centers, patients with chronic subdural hematoma (CSH) usually undergo serial CT in the post-operative period. However, debate remains on whether to continue with serial CT scanning for earlier detection of recurrence of CSH (with the risk of exposing the patients to excess radiation) or to only perform the CT after serial neurological examinations have shown the onset of neurological deterioration. A study is currently on-going to determine which protocol would be more suitable [17].

Performing serial scans comes with the challenge of ensuring reproducibility of the results in order to allow for a meaningful comparison of the radiological findings. When follow-up imaging studies are to be compared, the same imaging techniques should be used during each imaging session, .i.e. the strength of the MRI magnet must remain the same, the same dose of contrast must be given and images should be acquired after a specific post-contrast interval. Additionally, MRI and CT measurements must not be mixed [18].

Whenever intracranial tumor resection is to be followed by chemoradiotherapy, an immediate post-operative scan serves as a good baseline for future comparison. Evaluation of tumor progress becomes more challenging if there has been tumor resection prior to chemoradiotherapy. This is as a result of post-surgical brain changes that occur at the site of operation. Subsequent scans are then scheduled to be obtained at a time when some response can be demonstrated. The median time to response in progressive malignant gliomas was found to be 14 weeks, with 74% showing response by week 26[18, 19].

In addition to post-operative imaging, radiological studies can also be used during or just before the end of a surgical procedure. Post-operative imaging has previously been shown to be superior to surgical intra-operative evaluation for determination of completeness of surgery .This is important because residual tumor seems to be significant in the long term survival of the patient. Mobile CT/MRI scanners have been used intra-operatively to detect residual tumor. The immediate identification of residual tumor necessitates resumption of surgery to achieve a more complete resection before the patient leaves the operating room. The use of high-field intra-operative MRI has allowed a more extensive excision of tumors without additional postoperative neurological deficits .Furthermore a more extensive tumor resection is likely to result in a longer life expectancy for the patient [20, 21].

For the less aggressive tumors (such as pilocytic astrocytoma in children) long term surveillance to exclude recurrence can be avoided if the immediate postoperative scan demonstrates complete resection [22, 23 and 24].

The results of the cost-benefit analyses of radiological follow-up vary with different neurological conditions. For example, in patients with non-functioning pituitary adenomas, routine radiological follow up was found to be uneconomical. Regular Goldmann perimetry to examine the visual fields after steady state is achieved was more cost effective in determining patients in need of repeat surgical de-bulking and may reduce the number of scans to be performed [25]. Other follow-up strategies for pituitary adenomas that have been evaluated include hormonal testing and serial MRI. Compared to hormonal testing, repeat MRIs were found to be less cost effective in terms of Quality Adjusted Life Years (QALY) gained [26].

However, having found mixed results in the benefit of postoperative surveillance of different tumors of childhood; a separate study concluded that it is more effective to individualize the schedule of imaging studies to specific tumors, based on their pattern of recurrence. In this case, tumors with higher chances of recurrence showed benefit in regular postoperative imaging [27].

The economic value of post- operative CT scans has been demonstrated in patients who underwent stereotactic brain biopsy. In this study, absence of intracranial hemorrhage on CT scan was one of the three criteria used to allow an early discharge of patients from hospital after the procedure (the other two were the absence of intraoperative hemorrhage and the absence new post-operative deficit). This helped to reduce the indirect costs incurred due to extended hospital stay for observation [28].

2.5 Post-operative imaging findings following different cranial surgical techniques

It is important to recognize the expected post-operative changes before we identify abnormal findings.

A burr hole is small hole created in the calvarium using a surgical drill. In craniotomy, a portion of the skull is removed in order to expose the intracranial contents and replaced at the end of the procedure. In craniectomy, a portion of the skull bone is removed without replacement. Cranioplasty is achieved through autologous bone grafts or synthetic material. Acrylic cranioplasties are radiolucent and can be distinguished from the hyperdense titanium variety. Both return signal voids on MRI [5]. Ventriculo-peritoneal (VP) shunts are tubes that are usually implanted to relieve hydrocephalus.

Any neurosurgical technique may complicate with skull fracture, hemorrhage or infection. Burr holes are associated with plunging of the drill causing intracranial hemorrhage and formation of pseudomeningocele. Post-operative intracranial fluid collections will have a heterogeneous appearance on MRI due to varying contents of blood, CSF and air. Extradural hematomas may be classified as regional, adjacent or remote in relation to their location from the surgical site.

Some pneumocephalus should be expected during the first 3 weeks of the post-operative period and may be of little concern unless it is under tension.

Soft tissue infection will manifest as meningitis, extradural abscess, subdural empyema or brain abscess. The absence of diffusion restriction in a post-operative fluid collection does not reliably exclude the possibility of infection. On the other hand, the presence of blood degradation products may cause a false positive finding of restricted diffusion. Venous sinus thrombosis is a potential complication [29].

It is important to recognize the normal post-operative contrast enhancement that may occur in traumatized soft tissues and neovascular granulation tissue.

Complications of Craniectomy include extra cranial brain herniation, sub-dural or sub-galeal hygromas, external brain tamponade, trephine syndrome and paradoxical herniation [5]. The common complications of cranioplasty are late infection, autologous bone flap resorption and fracture of acrylic cranioplasties.

Ventriculo-peritoneal shunts may complicate with infections, over-drainage and mechanical stresses (occlusion, disconnection/fracture, migration) [30].

Brain changes at the site of operation include hemorrhage, edema and brain infarction. They will cause signal change on MRI as well as contrast enhancement along the margins of the tumor cavity. Therefore early post-operative imaging for assessment of residual tumor may be misleading unless it is done within 72 hours [4, 17].

Brain necrosis is seen between 6 months and 2 years post radiotherapy, and may be difficult to distinguish from residual or recurrent tumor because both show mass effect and ring enhancement on CT and MRI. A recurrent tumor should progressively enlarge on serial scans or demonstrate new sites of enhancement at the tumor bed. Difficult cases can be potentially resolved by MR spectroscopy, PET, SPECT or functional MRI [31].

The challenges facing radiological follow-up of intracranial tumors have been highlighted by considering the McDonald and RANO criteria which are commonly used to evaluate response of solid tumors to chemoradiotherapy in clinical trials. These have shown that it is difficult to determine the true extend of a tumor based on its enhancement pattern, since neither does all tumor mass enhance, nor is all enhancement necessarily caused by tumor. Because inter-observer variability is also recognized as a limitation, standard automated software that determines tumor progression may be required to transform the subjective interpretation into an objective analysis [9,29].

2.6 Summary

Computed tomography and MRI scans play a complimentary role in the evaluation of the post-operative cranium. The decision to undertake post-operative imaging should be tailored to the circumstances of an individual patient to ensure not only clinical appropriateness but also cost-effectiveness. The appropriate time for post-operative imaging should be guided by the indications for imaging. Accurate interpretation of post-surgical imaging studies requires knowledge of the normal cranial anatomy, the indications of the various surgical techniques and their normal post-operative appearances; as well as the expected complications.

3.0 METHODOLOGY

3.1 Study design and setting

A retrospective cross sectional cohort study was conducted at the Kenyatta National Hospital (KNH) Neurosurgical and Radiology units. KNH, a public health facility, is the main national referral hospital in Kenya and is located within Nairobi County. Services offered include generalized and specialized out-patient consultation services, casualty and emergency services, generalized and specialized investigative and therapeutic services and major and minor surgeries. Majority of the patients accessing generalized services are drawn from the hospital's catchment area while those accessing specialized services are drawn from beyond Nairobi County. The hospital has one Neurosurgical ward. Neurosurgical consultation is also carried out in other wards and at the out-patient clinic. A dedicated Neurosurgical operating theatre is used for elective surgical procedures while the trauma theater at the casualty department attends to emergency neurosurgical cases. The hospital's radiology department is comprised of general and specialized radiographic units, as well as sonography, fluoroscopy, CT and MRI sections. There is also a centralized registry where previous radiological films are archived.

3.2 Study Subjects

Study subjects were identified from neurosurgical theatre registers. They included patients operated between June 2011 and May2013.

Inclusion criteria:

- Any patient who underwent a cranial neurosurgical procedure during the study period
- Patients who were followed up at the neurosurgical outpatient clinic or remained in the wards or were on follow up in both the wards and the clinic for a maximum period of 6 months.

Exclusion criteria

- Patients who died during surgery.
- Patients with missing records.

3.4 Sample size calculation

Sample size estimation for this study was based on the assumption that only patients with neurological complications would have a post-operative imaging study. Davis et al, 2012, found that 20% of men and 11% of women would experience post-operative complications following neurosurgery [32].

The minimum sampled size (N) required for this study was determined using Fisher's formula. The formula states that:

$$N = \frac{Z^2 PQ}{d^2}$$

Where,

Z = Critical value for 95% confidence level / interval = 1.96.

P = Proportion of patients who will develop neurosurgical complications post operatively= 0.2.

Q =Proportion not developing neurosurgical complications = 0.8

d =the margin of error = 0.05.

$$N = \frac{1.96^2 * 0.2 * 0.8}{0.05^2} = 245.9$$

Therefore the minimum sample size, N required for this study = 246.

3.5 Data Management

3.5.1 Recruitment of study staff and role definition

A research team consisting of a consultant radiologist who had oversight over the lead researcher, 1 research assistant and a statistician were recruited. The assistant was employed on part time basis; he was a holder of a diploma in medical records and worked at the study site, his role was to retrieve medical records and to enter abstracted data from the data collection forms into the computer. The statistician helped to streamline the study design, to validate and to analyze the data. The study team undertook a one-day practical orientation to the study protocol/procedure and pilot tested the data collection tool.

3.5.2 Data collection methods and tools

Unique patient identifiers were assigned to each participant to maintain anonymity. A data collection tool was used to collect demographic information, preoperative diagnosis, presence of co-morbidities, type of surgery, date of surgery, date of discharge, admission to ICU, readmission after discharge, presence of postoperative scan, findings of the scan and subsequent surgical management from patient files (as shown in appendix I). For the patients whose files were not traced, we collected the minimum information that was available from registers in the operating theatres register. The pre-operative diagnoses were broadly grouped for the ease of analysis (table 1).

Table 1: Broad categorization of the preoperative diagnoses

Group diagnosis	**Components**
Tumor	Benign/ malignant neoplastic conditions
Trauma	Skull fractures, intracranial hemorrhages
Pyogenic infections	Brain abscess, subdural empyema, osteomyelitis of the skull bones.
Hydrocephalus	Hydrocephalus, v-p shunt malfunction.
Others (less frequent)	Cerebral vascular aneurysms, Arnold Chiari malformation.

For patients with more than one disease entity the type of surgery recorded depended on the lesion being addressed on the particular day. The scans ordered were classified as ‘urgent’ when there was a neurological derangement to be addressed e.g. when the patients’ condition remained unsatisfactory or there were new or worsening clinical features [13], and ‘routine’ when they were requested for follow-up, reasons. Imaging studies were performed on a 16-slice helical CT scanner and/or a 1.5 Tesla Philips-Intera MRI scanner at KNH.

The imaging findings were collected from the radiological reports as documented by the consultant radiologist. In cases where the radiological reports were not accessible, the films were evaluated by the lead researcher who then sought concurrence from the consultant radiologist before entering the findings into the data collection forms.

The type of imaging findings on postoperative scans were considered as 'post-surgical changes' (non-pathological) where scan findings were unremarkable; otherwise type of imaging finding were considered 'positive' (pathological).In case a single patient had a repeated surgical procedure; each new post-operative scan was evaluated independent of the previous scans. The duration of hospital stay was calculated as the time between date of surgery and date of discharge or death.

Data was collected using paper data collection tools and entered into an excel spreadsheet on a laptop computer and was then imported into SAS 9.2for analysis.

3.5.3 Data Analysis

Chi square statistics were used to compare characteristics of patients whose files were traced to those whose files could not be traced [33].Frequency summaries and logical steps were be used to identify missing information and outliers. Chi square statistics and fishers exact tests were used to compare proportions of patients who received imaging studies to those who did not. T tests were used to compare continuous variables e.g. age, between patient categories. Kaplan Meier Curves were used to illustrate the time to imaging study for patients who had a scan within 6 months of surgery. Cox proportional hazards were used to describe factors influencing time to imaging scan. Cochrane-Mantel-Haenszel analysis was used to describe the relationship between the time to imaging study and findings of the imaging studies.

3.6 Ethical Considerations

Ethical approval to conduct this study was sought and obtained from the Kenyatta National Hospital/ University of Nairobi Ethical Review Committee prior to the conduct of the study (P498/10/2013). Informed consent to access participant records was obtained from the Hospital's Administrator and section heads from where data was to be drawn (Appendix III).

All participant records were anonymized. A participant link log was separately retained by the principal investigator in the event re-retrieval of patient records was required. All study materials (including this log) were kept under lock and key with only specific study personnel who had signed confidentiality agreement forms (See appendix IV) were allowed access to study materials. All raw data was scheduled to be destroyed within 2 years of completion of the study.

4.0 RESULTS

4.1 Study cohort

A total of 298 patient files were retrieved of whom 42 (14%) were lost to follow up and 8 (2%) died within 6 months of surgery. Among those who were no longer followed up at the study site (KNH), 2 cases were documented to have been transferred out to a lower level of care while 1 absconded from the hospital ward. The rest were not seen on their outpatient clinic return dates and their outcomes remained unknown. However, 248 (83%) patients remained alive at the end of 6 months following surgery.

The majority of patients who underwent cranial surgery were aged 15-49 years (130; 48%), male in gender (200; 67%). Trauma was the most common indication for the initial surgery (132; 44%). Majority of the surgical procedures were elective (183; 61%), while the most common type of surgery was craniotomy (168; 57%). Most patients stayed in the hospital for less than 1 month after surgery (n=244; 82%).

Few patients had co-morbidities (36; 12%), required ICU admission in the post-operative period (56; 19%) and were readmitted during the study period (22; 7%); (Table 2).

4.2 Proportion of patients who had post-operative scans

Of the patients who underwent cranial surgery, 81 (27%) had post-operative scans ordered within 6 months of surgery of whom 28 (35%) did not have results of imaging study documented and were therefore excluded from this analysis. Patients who had scan results documented compared did not differ from those who did not have scan results documented. Of the 53 patients (18% of the total patients who underwent surgery) who had an imaging study, 47 (89%) had single CT scans, 3 (5 %) had single MRI scans, 2 (4%) had 2 CT scans and 1(2%) had a single CT followed by a single MRI scan.

Patients who had an imaging study were significantly more likely to have, had elective craniotomies for tumors; been admitted in the ICU post operatively, been readmitted to hospital within the follow up period and to be alive at the end of the follow up period. However, these patients were less likely to have had a short (<1month) duration of hospital stay (Table 2 and 3).

<u>Table 2:</u> Characteristics of patients who underwent cranial surgery at Kenyatta National Hospital and proportions that had post-operative scans between June 2011 and May 2013

Patient characteristics	**Total number N=298 (100%)**	**Had a scan N=53 (18%).**	**Did not have a scan N=245 (82%).**	**P value**
Age Group[¥]				
<15 years	79 (29)	18 (27)	61 (37)	0.5
15-49 years	130 (48)	22 (49)	108 (45)	
50-64 years	40 (15)	5 (16)	35 (10)	
65+ years	21 (8)	4 (8)	17 (8)	
Gender				
Male	200 (67)	37 (70)	163 (67)	0.6
Female	98 (33)	16 (30)	82 (33)	
Indication for surgery[#]				
Trauma	132 (44)	12 (23)	120 (49)	<0.0001
Tumor	91 (30)	27 (51)	64 (26)	
Hydrocephalus	40 (13)	4 (7)	36 (15)	
Pyogenic infection	19 (6)	9 (17)	10 (4)	
Others	16 (5)	1 (2)	15 (6)	
Urgency of surgery				
Elective	183 (61)	46 (87)	137 (56)	<0.0001
Emergency	115 (39)	7 (14)	108 (44)	
Type of surgery[¶]				
Craniotomy	168 (56)	40 (75)	128 (52)	0.0002
Burr hole	64 (22)	3 (6)	61 (25)	
V-P shunting	40 (14)	3 (6)	37 (15)	
Elevation of depressed skull fracture	16 (5)	2 (4)	14 (6)	
Others	10 (3)	5 (9)	5 (2)	
Presence of co-morbidity[π]				
Present	36 (12)	7 (13)	29 (12)	0.8
Absent	262 (88)	46 (87)	216 (88)	
ICU admission				

Yes	56 (19)	23 (43)	33 (13)	<0.0001
No	242 (81)	30 (57)	212 (87)	
Duration of Hospital admission				
<1 month	244 (82)	32 (60)	212 (86)	0.0001
1-2 months	29 (10)	12 (22)	17 (7)	
2-3 months	12 (4)	5 (10)	7 (3)	
3 months +	13 (4)	4 (8)	9 (4)	
Readmission after discharge from hospital				
Yes	22 (7)	13 (25)	9 (4)	<0.0001
No	276 (93)	40 (75)	276 (96)	
Patient outcome				
Alive	248 (83)	51 (96)	197 (80)	0.0048
Dead	8 (3)	2 (4)	6 (3)	
Lost To Follow Up	42 (14)	0 (0)	42 (17)	

[¥]28 patients missing age documentation

[#]other indications for surgery included Arnold Chiari malformation, vascular aneurysm and Cerebrovascular accidents.

[¶]Other types of surgery included Endoscopic third ventriculostomy, External ventricular drainage and Trans-sphenoidal hypophysectomy.

πThe co-morbidities included hypertension, diabetes mellitus, septicemia, anemia, myelomeningocele, low birth weight, cerebral palsy and other tumors.

4.3 Indications for postoperative cranial imaging

Of the 53 patients with post-operative imaging studies, 21 (40%) had routine scans for follow up reasons; majority of these patients had undergone elective craniotomy (16; 76%) for tumor (12; 57%). The other 32 (60%) had urgent scans for various indications. An altered state of consciousness was the commonest neurological derangement that prompted urgent scanning of the patients. The rare indications grouped as 'others' included aphasia, cranial nerve palsy and focal paresis. The distribution of indications for initial scanning among patients who had urgent scans is shown in figure 1 below.

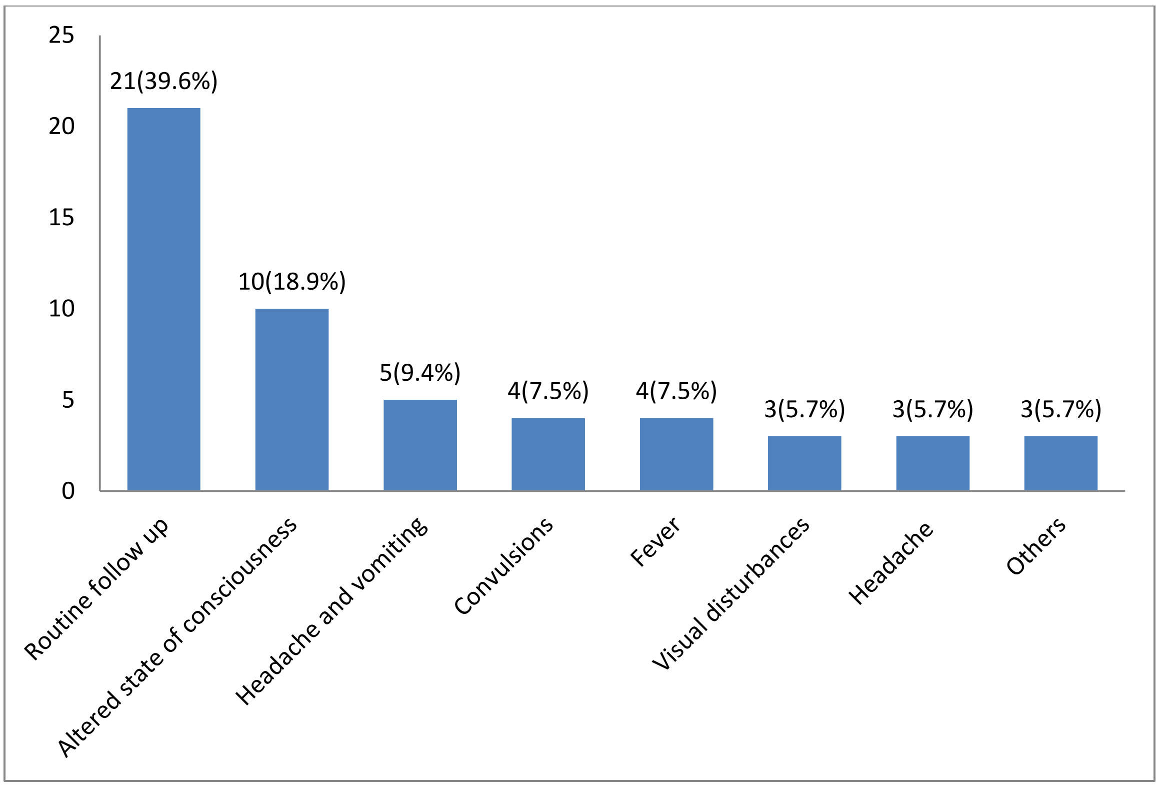


Figure 1(above): *Showing the number (%) of patients (vertical axis) who had post-operative scans for various indications (horizontal axis).*

Majority of the patients (50; 94%) had a single imaging study done and among them CT scanning was the most common imaging modality chosen (47; 97%). Three of the 53 patients (6%) had repeat scanning done after their first scan; all of the initial scans were urgent, for focal neurological deficit, altered level of consciousness and visual disturbance. Two of the three follow up scans were routine and 1 one was urgent for confusion and convulsions.

4.4 Time to imaging study

After 6 months of surgery, less than a quarter of patients had undergone an imaging study. Only 53 (18%) of all the 298 (100%) patients who underwent surgery had an imaging study done by the 6^{th} post-operative month (Figure 2).

Among the 53 (18%) patients who had an imaging study done within 6 months of surgery, the median time to having a scan was 20 days with a mean of 37.8 days, mode of 15 days, range of 1-162 days, and inter-quartile range of 12-49 days after surgery. For patients who had undergone emergency surgery, the time-to-scan was significantly shorter than for patients who had undergone elective surgery (median=12 days; IQR= 4-16 days vs. median=23 days; IQR= 13-52 days respectively; $p=0.01$). The time to imaging study was shorter for patients who had a longer duration of hospital admission and for patients who were readmitted within 6 months following cranial surgery ($p<0.0001$) (Figure 3, Figure 4). This time did not significantly differ among patients who had routine scans compared to patients who had urgent scans.

Figure 2: Time from Surgery to Imaging Study for all patients who Underwent Cranial Surgery between July 2011-May 2013 at Kenyatta National Hospital

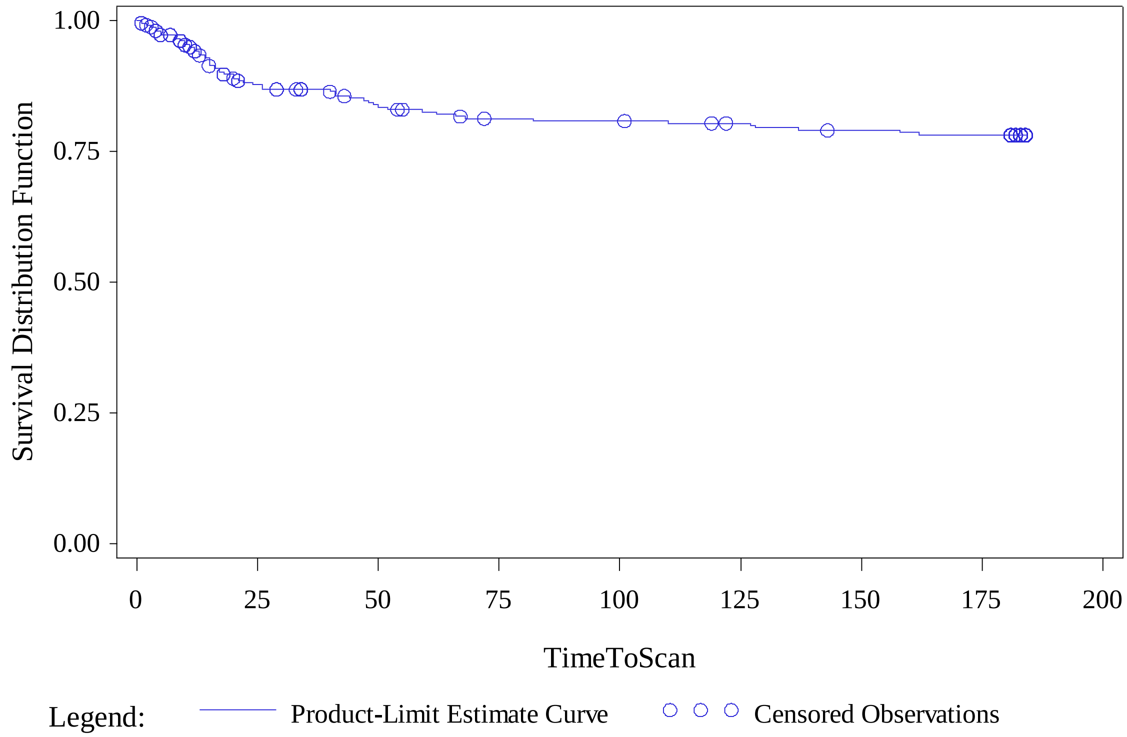


Figure 3 below is a survival analysis (Kaplan Meir curve) showing the proportion of patients who were yet to have a post-operative scan (vertical axis) against time in days (horizontal axis). The patients were followed for a maximum of 180 days. The curves represent different durations of hospital stay. The patients who stayed for less than 1 month had the least chances of getting a scan **(top curve)** while those who stayed for between 1-2 and 2-3 months had the highest chances **(the 2 bottom curves).** Extending hospital stay beyond 3 months **(second curve from top)** did not increase the chances of getting a scan

Figure 3: Time from Surgery to Imaging Study for all patients who underwent Cranial Surgery between July 2011-May 2013 at Kenyatta National Hospital, KNH, by duration of hospital admission

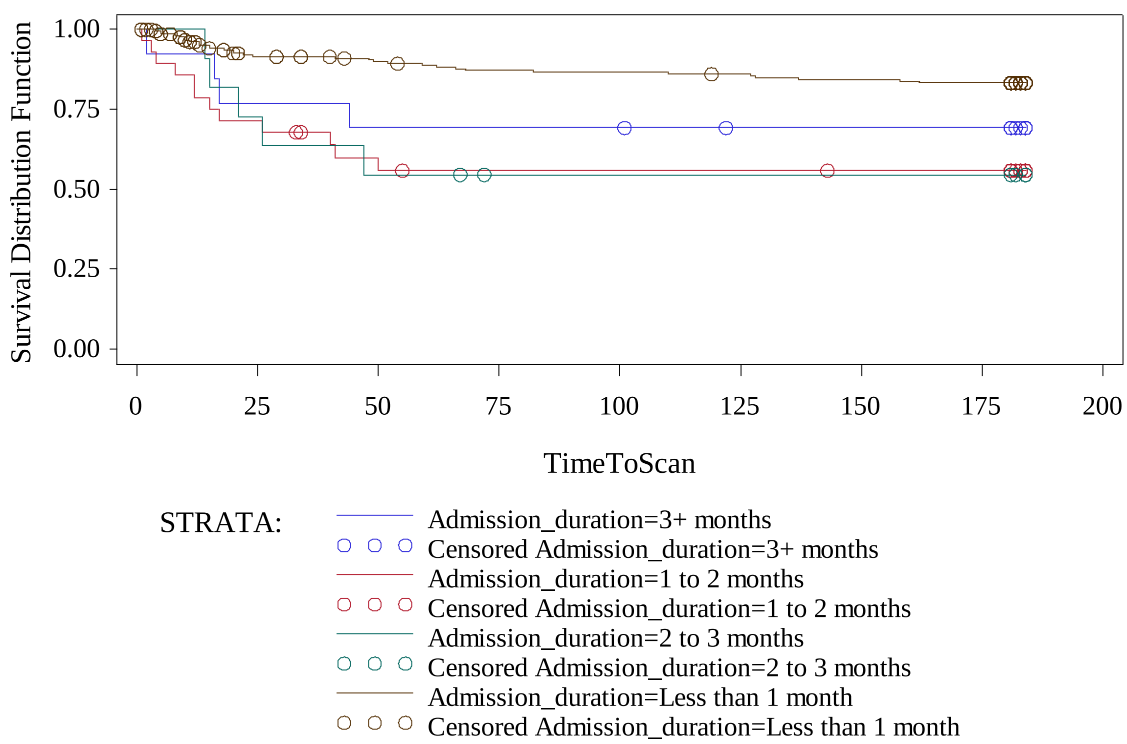
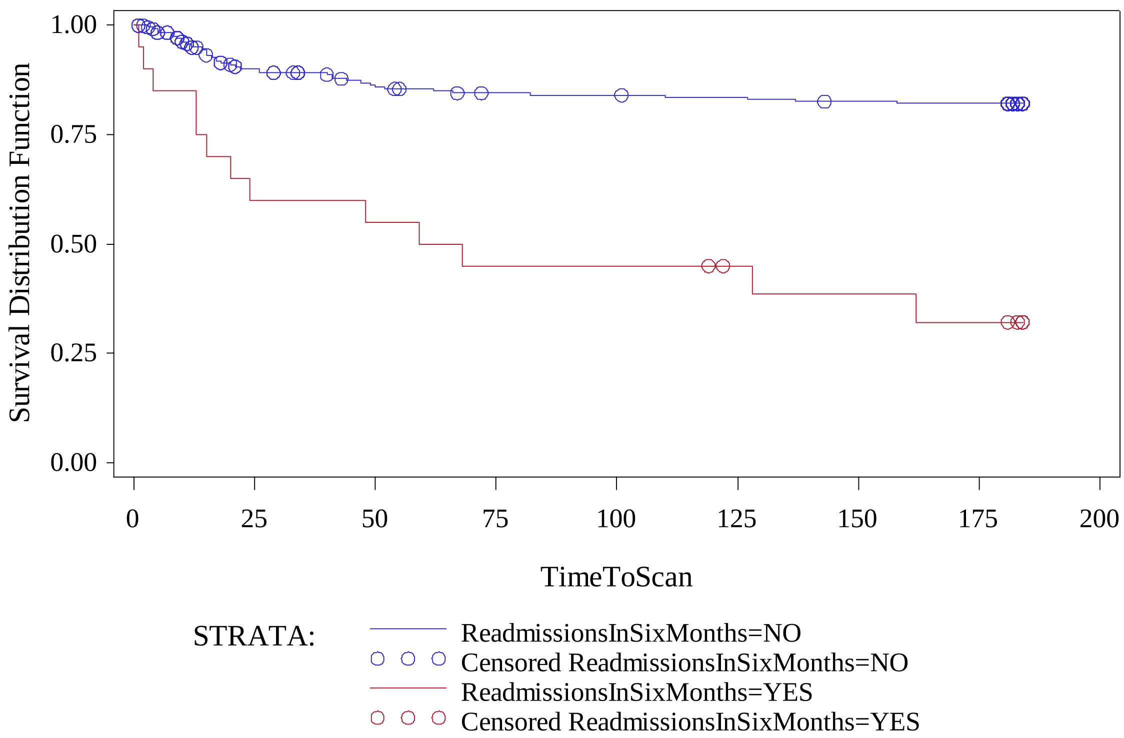


Figure 4: Time from Surgery to Imaging Study for all patients all patients who underwent Cranial Surgery between July 2011-May 2013 at Kenyatta National Hospital, by readmission status.



4.5 Factors influencing time to imaging study

Patients who had elective surgeries, who were readmitted within 6 months following surgery, those who had craniotomies and had a hospital admission of between 2 to 3 months had a shorter duration to imaging study (Table 3).

Table 3: Factors influencing time to Imaging Study among patients who underwent cranial surgery between July 2011 and May 2013

Patient characteristics	Univariate analysis- Hazard Ratio (95% CI)	P value	Multivariate analysis- Hazard Ratio (95% CI)	P value
Age Group[¥]				
<15 years	Ref			
15-49 years	0.7 (0.4-1.3)	0.2		
50-64 years	0.5 (0.2-1.4)	0.2		
65+ years	0.8 (0.3-2.4)	0.7		
Gender				
Male	Ref			
Female	0.9 (0.5-1.5)	0.6		
Indication for surgery[#]				
Trauma	Ref			
Tumor	3.3 (1.6-6.6)	<0.0001	0.4 (0.1-1.5)	0.0295
Hydrocephalus	1.1(0.4-3.4)		0.4 (0.1-6.2)	
Pyogenic infection	7.1 (2.9-16.9)		1.1 (0.3-4.1)	
Others	0.6 (0.1-4.5)		0.05 (0.1-0.4)	
Urgency of surgery				
Emergency	Ref			
Elective	4.1 (1.9-9.2)	0.0005	3.5 (1.1-12.1)	0.0413
Type of surgery[¶]				
Craniotomy	Ref			
Burr hole	0.2 (0.1-0.6)	0.0044	0.2 (0.1-0.8)	0.0034
VP shunting	0.3 (0.1-0.9)		0.2 (0.04-2.0)	
Elevation	0.5 (0.1-1.8)		0.5 (0.09-2.5)	
Others	2.0 (0.8-5.2)		3.7 (1.2-11.9)	
Presence of co-morbidity				
Absent	Ref			
Present	1.2 (0.5-2.6)	0.7		

ICU admission				
No	Ref			
Yes	3.7 (2.2-6.4)	<0.0001	3.4 (1.7-6.7)	0.0005
Duration of Hospital admission				
< 1 month	Ref			
1-2 months	3.8 (1.9-7.4)	0.0002	4.6 (2.2-9.4)	0.0003
2-3 months	3.5 (1.4-8.9)		3.5 (1.2-10.4)	
3 months +	2.5 (0.8-6.9)		1.8 (0.5-6.2)	
Readmission after discharge from hospital				
No	Ref			
Yes	5.3 (2.8-9.9)	<0.0001	5.6 (2.7-11.5)	<0.0001

4.6 Findings on postoperative scans

4.6.1 Summary of findings

Of the 53 patients with post-operative imaging studies, 17(32%) patients had expected post-surgical changes (non-pathological or unremarkable findings), 12 (23%) had residual masses, 7 (13%) had hydrocephalus or VP shunt complications, 6 (11%)had pyogenic infection, 5 (9%) had large subdural hygroma, 3 (6%) had pseudomeningocele, 2 (4%) had foreign bodies and 1(2%) had a large intracranial hematoma (Figure 5).

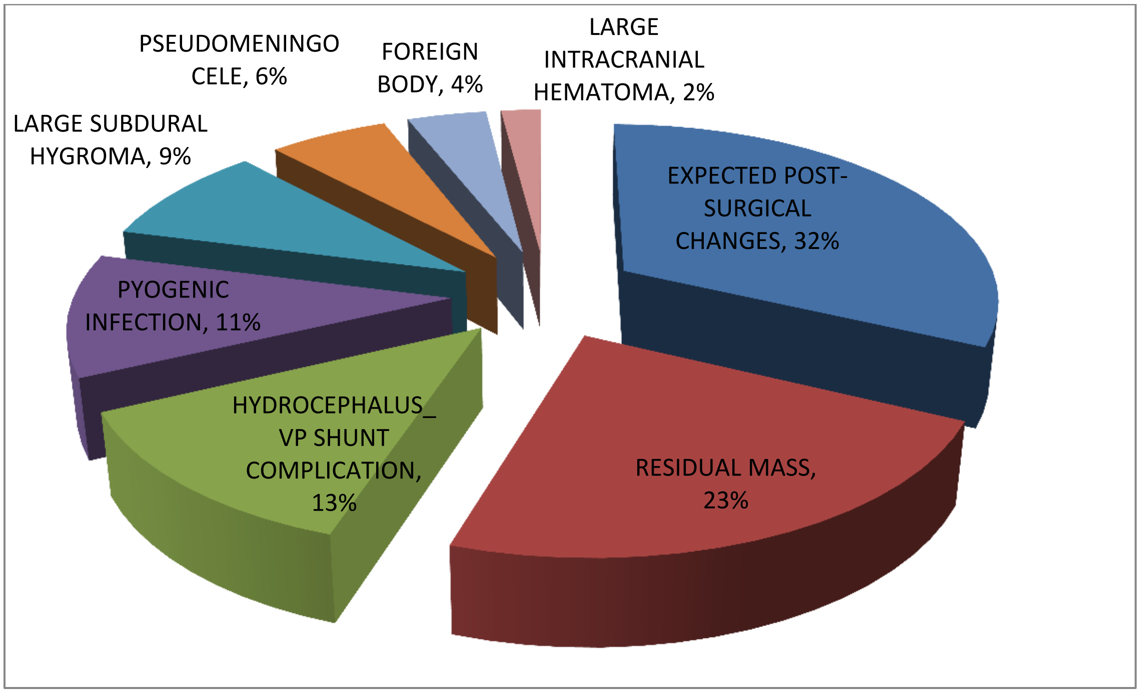
Of 21 (40%) patients who had routine scans, 8 (38%) had expected post-surgical changes, 5(24%) had residual masses, 3(14%) had pyogenic infection, 2(9.5%) had pseudomeningocele, 2 (9.5%) had large subdural hygromas, and 1 (5%) had a bullet shrapnel.

Of the 32 patients who had urgent scans, majority (23; 67%) had pathological findings and the remainder (n=9) had non-pathologic findings. Imaging findings for the patients with urgent scans are summarized below:

- 10 patients with altered states of consciousness had expected post-surgical changes (4), residual mass (2), large sub-dural hygroma (2) and hydrocephalus or VP shunt complications (2),
- 5 patient with features of raised ICP had expected post-surgical changes (3) and hydrocephalus or VP shunt complications (2),
- 4 patients with convulsions had hydrocephalus or VP shunt complications (2), residual mass (1) and large subdural hygroma (1),
- 3 patients with fever had hydrocephalus or VP shunt complications (2) and pyogenic infection (1),
- 3 patients with headache had large intracranial hematoma (1), residual mass (1) and post-surgical changes(1)
- 3 patients with visual disturbance had pyogenic infection (1), expected post-surgical changes (1) and residual mass (1),
- one patient with wound infection had pseudomeningocele,
- one patient with focal neurological deficit had a residual mass,
- one patient with cranial nerve palsy had a residual mass,
- one patient with aphasia had a foreign body
- One patient with confusion had hydrocephalus or VP shunt complications

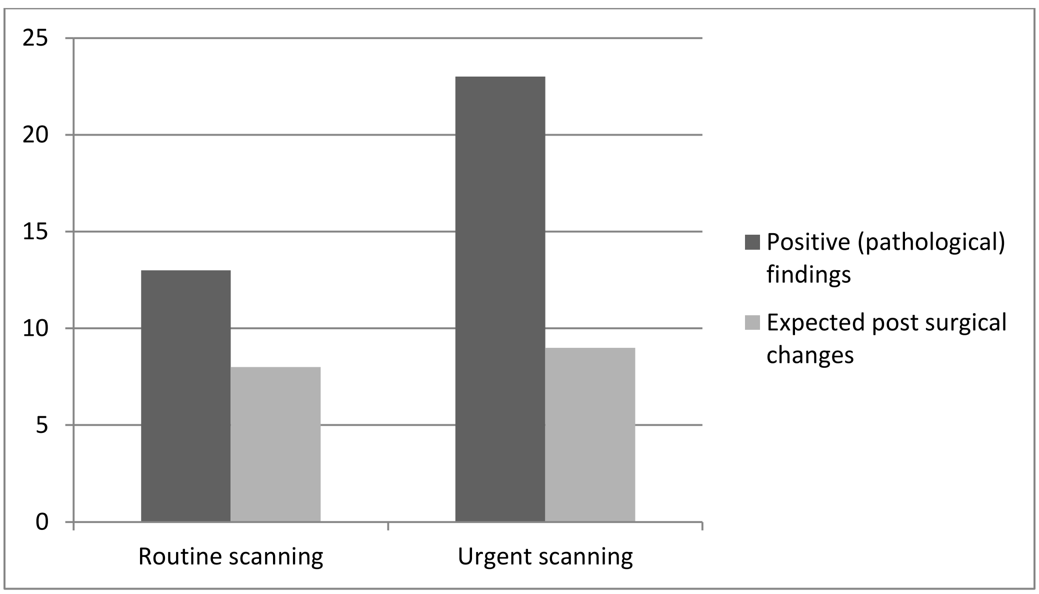
Three of the 53 patients (6%) had repeat scanning done after their first scan; all the three scans were urgent. Two of the scans showed residual masses and the one scan showed an infarct. On repeat scanning, two of the routine scans showed residual masses and the urgent scan showed raised intracranial pressure.

Figure 5: Summary of findings visualized on radiological imaging for select neurosurgical patients operated between July 2011 and May 2013 at Kenyatta National Hospital.



Positive findings were more common in scans obtained for urgent indications as opposed to routine scanning (figure 6). Fever and convulsions were the indications that were invariably associated with a positive scan finding. The association of positive scan findings with the duration of hospital stay, post-operative ICU admission and hospital readmission within 6 months did not achieve statistical significance in the multivariate analyses.

Figure 6(below) *shows the prevalence (number) of 'positive' vs 'expected' findings seen among patients who had urgent post-operative scans (with neurological derangement) compared to those who had routine post-operative scans.*



4.6.2 Sample images for neurosurgical patients operated between July 2011 and May 2013 at Kenyatta National Hospital who underwent post-operative scans within 6 months of surgery

In this section a sample of images (both CT and MRI) for the 2011-2013 cohort that were seen pre and post operatively are shown. Some pre-operative images are included to facilitate the demonstration of the changes caused by the surgical procedures.

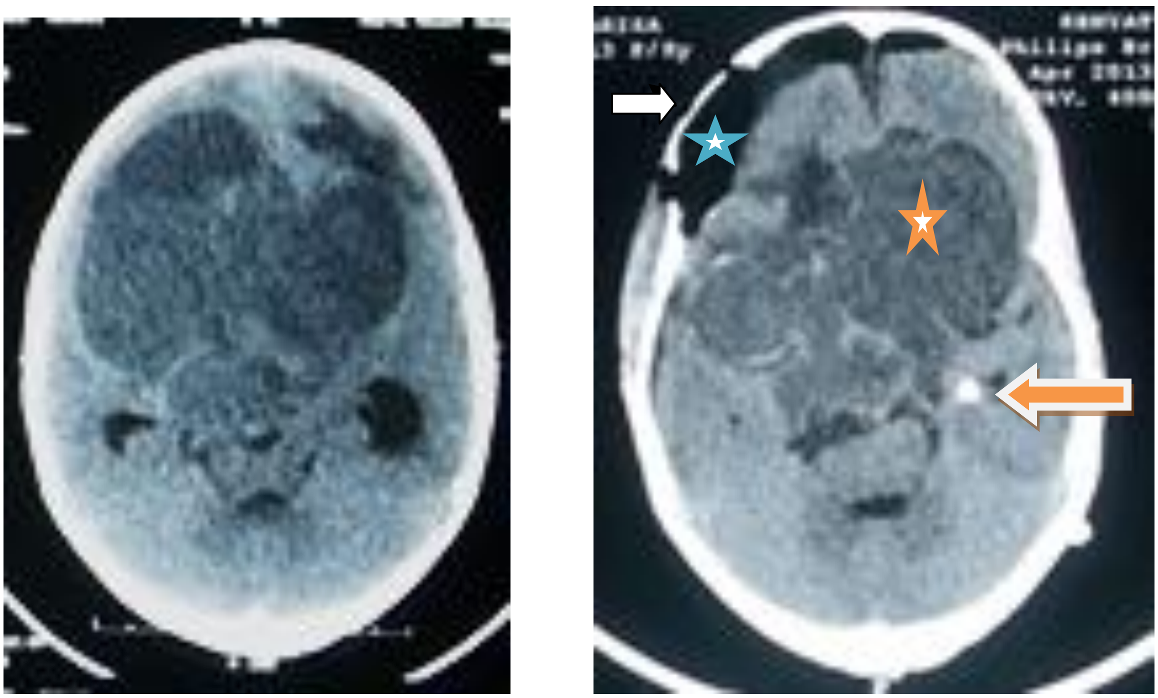


Figure 7:

Left: *Pre-operative non-contrast enhanced CT scan of an 8 year old child with a suprasellar tumor whose histology was pilocytic astrocytoma.*

Right: *One week after surgery, the post-operative CT scan shows the bone flap at the right frontal/parietal craniotomy site (white arrow), bi-frontal pneumocephalus (blue star) and a large residual mass (red star). There is a left sided venticuloperitoneal (VP) shunt (red arrow) causing decompression of the ventricular system.*

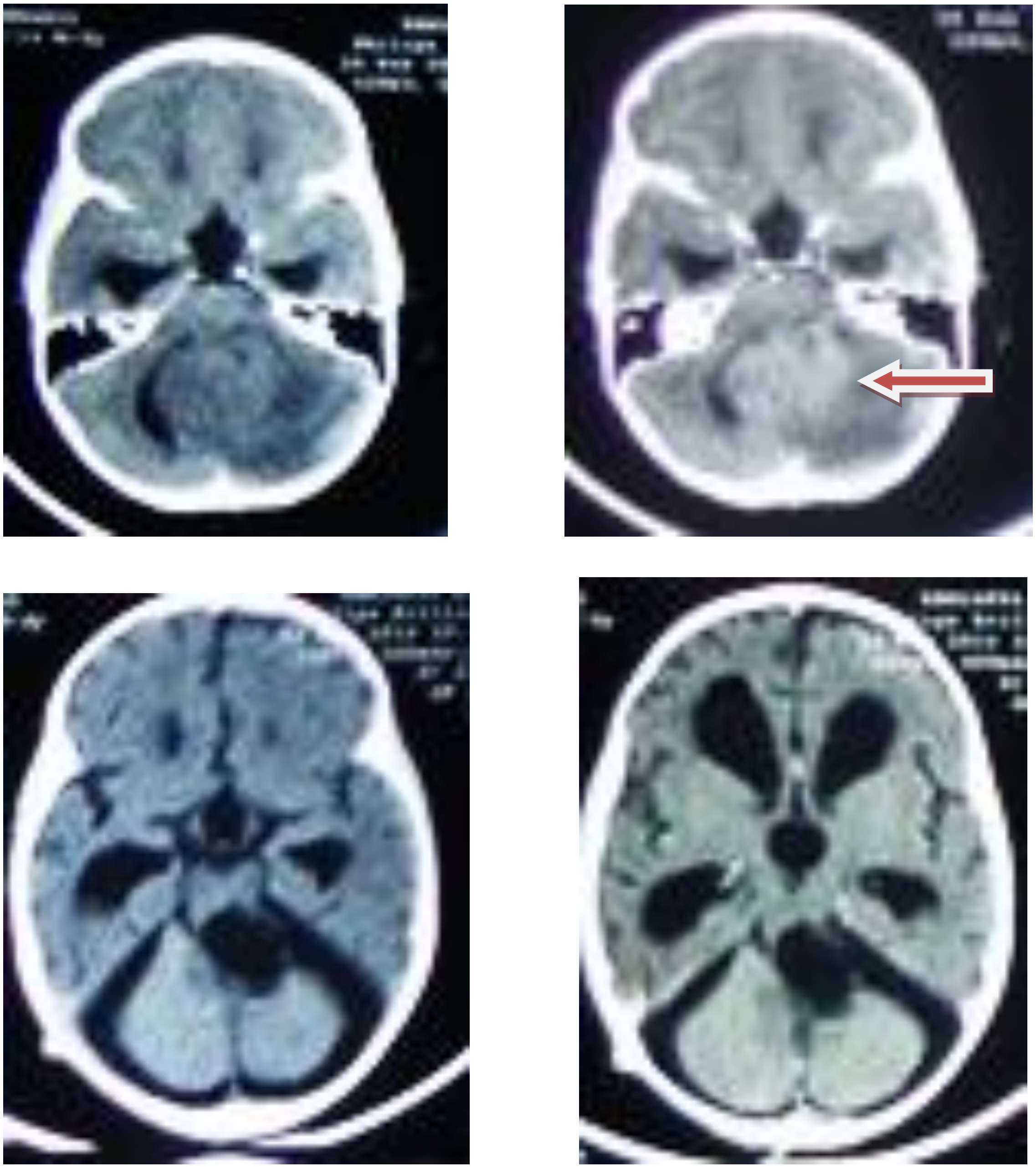


Figure 8:

Top row: *Pre- and post-contrast CT scans showing a moderately enhancing posterior fossa mass (arrow) causing hydrocephalus. This was seen in a 6 year old child and its histology was astrocytoma (WHO grade 1).*

Bottom row: *Post-operative scans done two weeks after surgery. Absence of enhancement on the surgical margin is consistent with total excision of the tumor.*

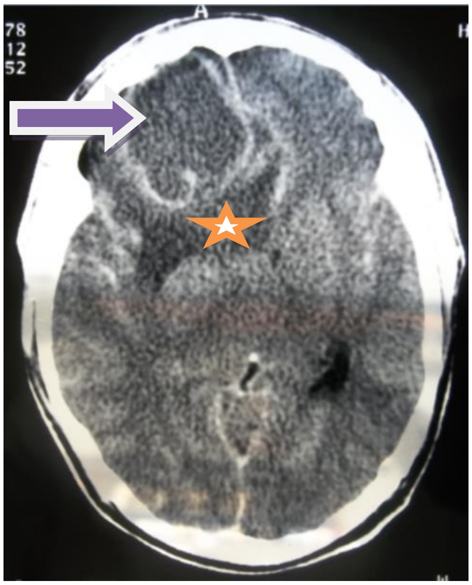


Figure 9:

A hypodense collection (arrow) with a thick wall and peri-lesional edema (star) was found in a patient who previously had a depressed skull fracture that was surgically elevated. Subsequent surgery was required to drain this abscess.

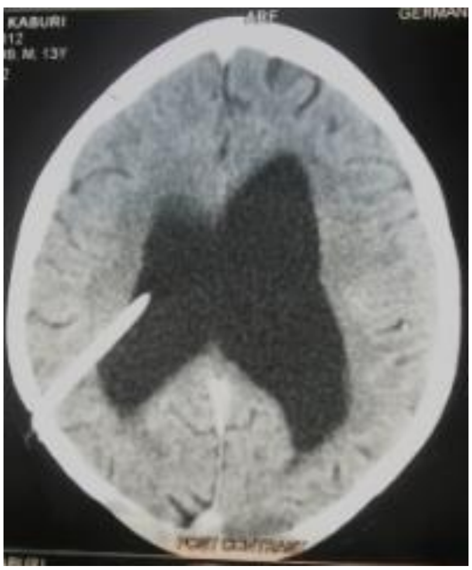
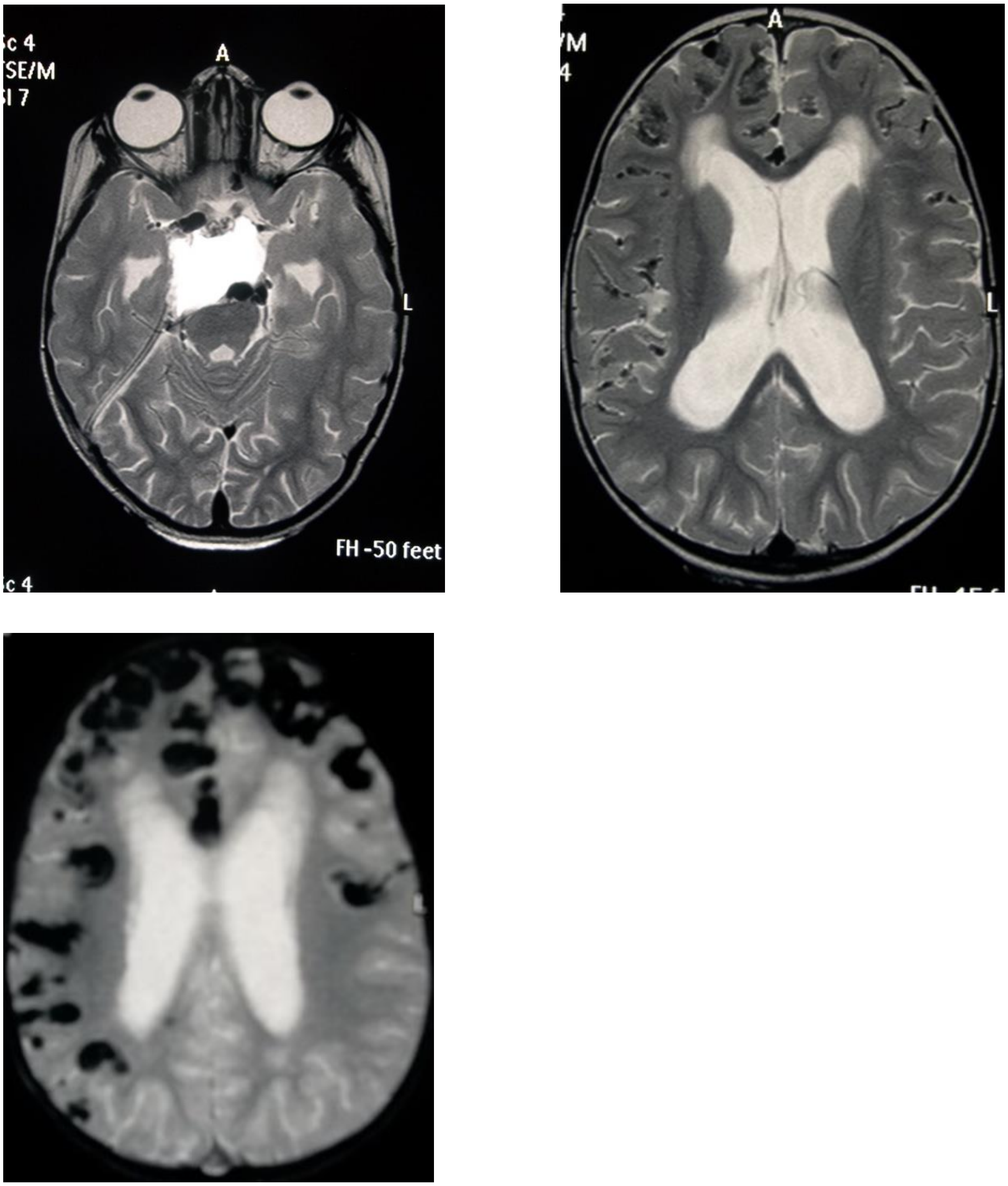


Figure 10:

***Top right**: CT scan of a child with hydrocephalus. The lateral ventricles are still dilated in spite of the VP shunt in place. Previous scans are useful for assessing progress.*



<u>Figure 11:</u>

Top Left: *T2W MRI of a child with a VP shunt inserted recently to relieve hydrocephalus secondary to a suprasellar tumor.*

Top right: *The frontal/parietal lobes of the brain have widespread signal voids which become exaggerated on the gradient image* ***(bottom right)****.This was post-surgical pneumocephalus. History of a recent cranial surgery and comparison with pre-operative images can distinguish this from hemorrhage or calcifications.*

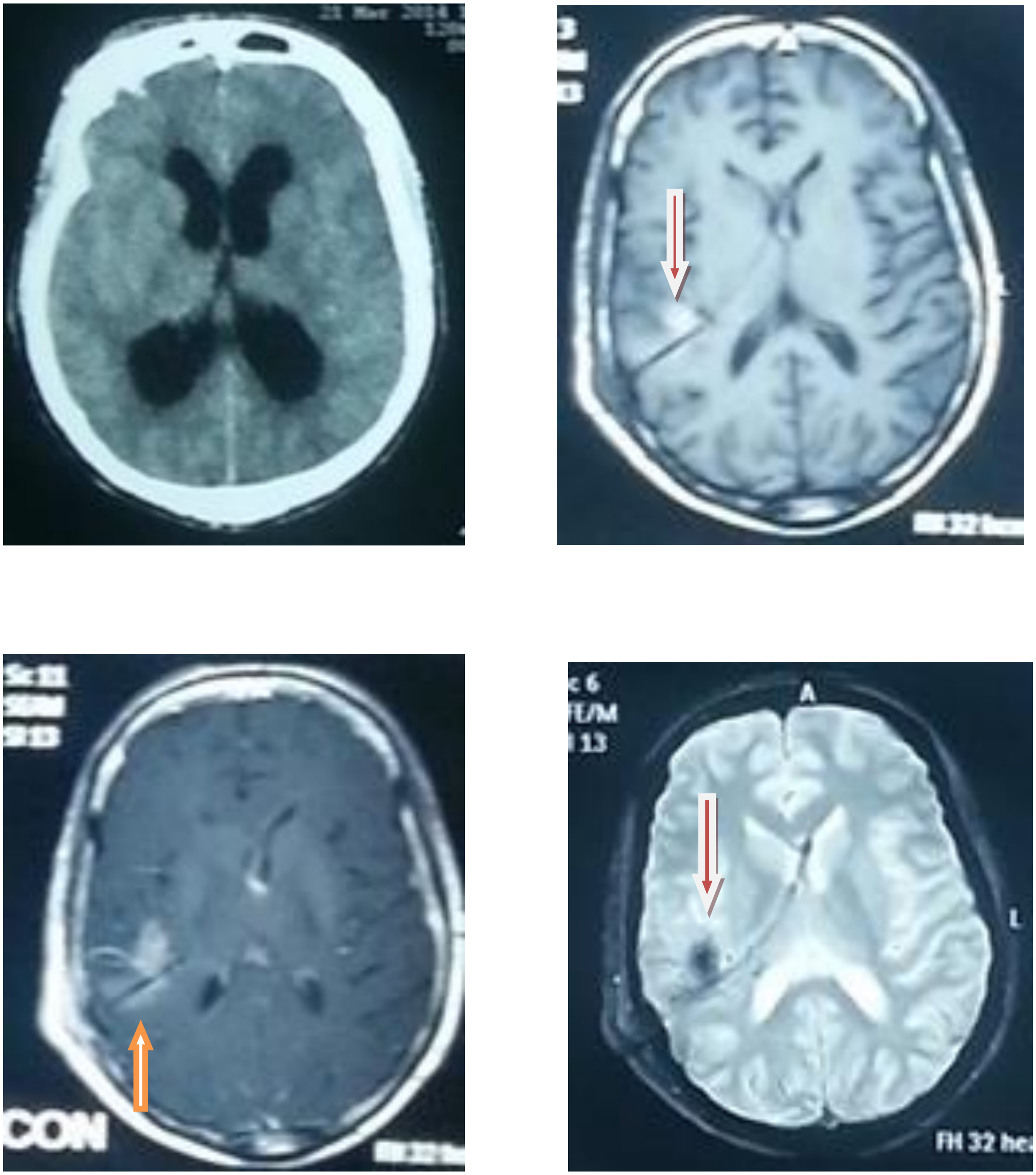


Figure 12:

Top left: *CT scan of a patient with hydrocephalus.* ***Top right:*** *TIW MRI of the same patient, two weeks after insertion of a VP shunt. There is resolution of hydrocephalus and hyper-intense signal changes are seen along the track of the VP shunt.T1W+C-* ***(Bottom left)*** *shows contrast enhancement along the track of the shunt and gradient blooming artifact* ***(Bottom right****)* *confirms post-surgical hemorrhage.(Arrows)*

4.7 Relationship between timing of imaging study post-operatively and findings visualized

Thirty six (68%) of the 53 patients who underwent post-operative imaging had pathological findings on imaging study. The proportion of patients with pathological findings did not differ by timing of the scan irrespective of the scan type (routine vs urgent).

Patients who had routine scans done within 30 days of surgery had somewhat similar findings to those who had a scan done more than 30 days after surgery; similar findings were observed for patients who had urgent scans (Table 4).

Table 4: Relationship between Imaging findings, time to scan and type of post-operative scan requested for patients who underwent cranial surgery at Kenyatta National Hospital between July 2011 and May 2013

	Pathology found	No pathology found	Total	P value
Routine scans	**12 (57%)**	**9 (43%)**	**21(40%)**	**0.08**[‡]
Time to scan <30 days	5	6	11	0.4[#]
Time to scan ≥30 days	7	3	10	
Urgent scans	**24 (75%)**	**8 (25%)**	**32 (60%)**	
Time to scan <30 days	15	7	22	0.4[¶]
Time to scan ≥30 days	9	1	10	
Totals	**36 (68%)**	**17 (32%)**	**53 (100%)**	

[‡]Cochran-Mantel-Haenszel test comparing time to scan by presence or absence of pathology controlling for scan type (routine vs. urgent)

[#]Fisher's exact test comparing time to scan and pathology findings for patients with routine scans

[¶]Fisher's exact test comparing time to scan and pathology findings for patients with urgent scans

4.8 Surgical Intervention after cranial imaging

Twenty one of 53 patients (40%) had a surgical intervention after imaging, 11 (52%) of these patients had recurrent/persistent findings while 10 (48%) had new findings.

For the 10 patients with new findings, imaging findings were hydrocephalus or VP shunt complications (4; 40%), large subdural hygroma (4; 40%), pseudomeningocele (1; 10%) and pyogenic infection (1; 10%), for the 11 patients with recurrent/persistent findings they were, pyogenic infection (4), residual tumor masses (4), hydrocephalus or VP shunt complications (2), and large intracranial hematoma (1).

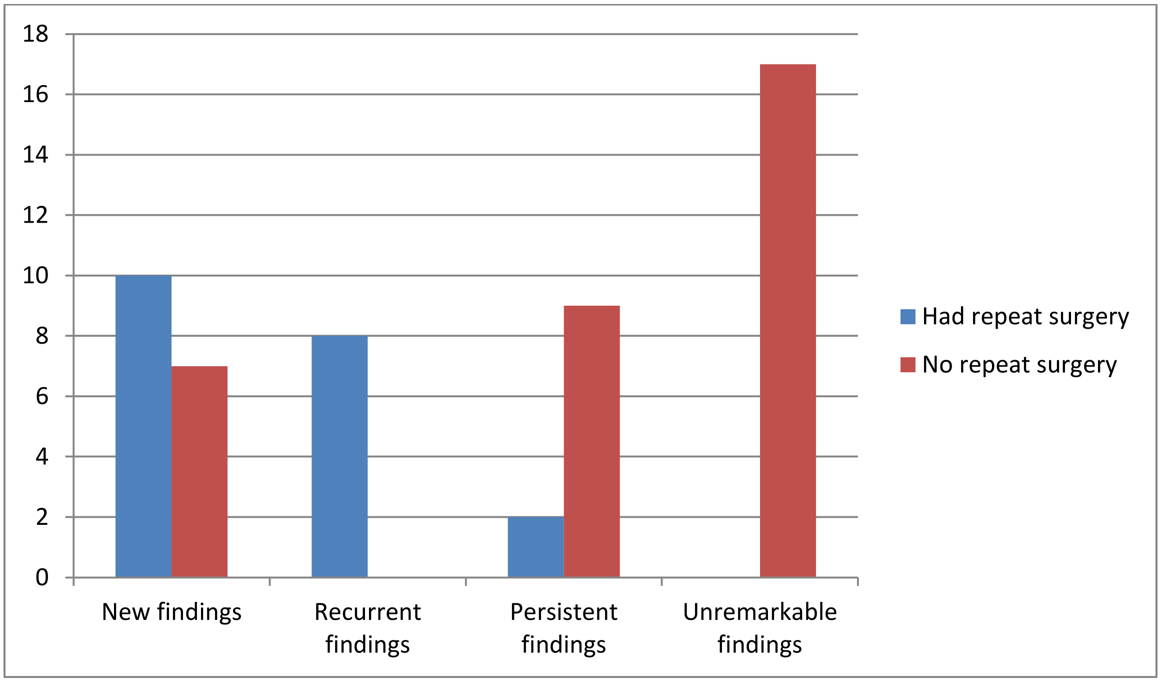
Patients who did not have a surgical intervention after imaging (n=32, 60%) had unremarkable/non-pathologic findings (also referred to as expected post-surgical changes) on imaging study (17; 53 %), persistent findings (8; 25 %) or new findings (7; 22 %). The 9 patients with persistent findings had residual masses and among the 7 patients with new findings 2 had pseudomeningocele , 2 had bullet fragments, 1 had pyogenic infection , 1 had a large subdural hygroma , and 1 had brain edema and ventriculomegaly. These findings are summarized on figure 13.

Patients with urgent scans were more likely to have had a surgical intervention after imaging compared to patients with a routine scan requested, (n=17;53% vs. n=3;14% respectively; p=0.005, C.I=95%), (Figure 14).

Patients who were admitted to ICU in the post-operative period were *less* likely to have a repeat surgical intervention (p=0.03, CI=95%). Age group, gender, preoperative diagnosis, type of surgery, readmission after discharge within the study period (6 months), and the time at which the postoperative scan was done did not affect the likelihood of surgical intervention after an imaging study (Table 5).

Two of the three who had repeat scanning done after their first scan had repeat surgery after initial scans showed residual masses; the third patient who had an infarct did not have repeat surgery. On repeat scanning that showed residual mass, expected post-surgical changes and raised intracranial pressure, repeat surgery was not done.

Figure 13 (below): *Showing the number of patients who had a repeat surgical procedure (vertical axis) depending on the type of findings (horizontal axis) of the post-operative scan.*



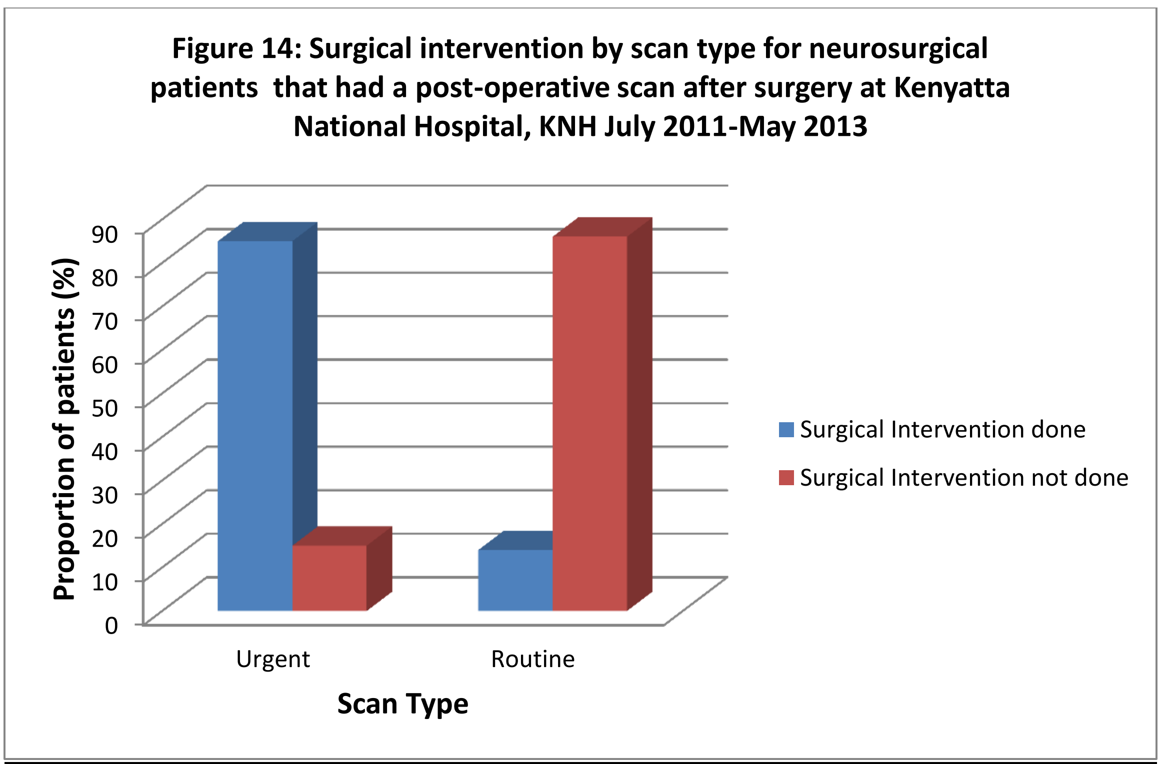


Table 5: Factors influencing chances of having a repeat surgical intervention for neurosurgical patients who underwent post-operative scanning within 6 months of surgery at Kenyatta National Hospital, KNH, July 2011- May 2013

Patient characteristics	**Univariate analysis- Odds Ratio (95% CI)**	**P value**	**Multivariate analysis- Odds Ratio (95% CI)**	**P value**
Age Group[¥]				
<50 years	Ref			
50+ years	1.3 (0.3-6.1)	0.3		
Gender				
Male	Ref			
Female	0.9 (0.5-1.5)	0.5		
Indication for initial surgery[#]				
Trauma	Ref	0.4		
Tumor	2.1 (0.5-8.6)			
Hydrocephalus	0.7 (0.1-6.9)			
Pyogenic infection	0.6 (0.1-3.3)			
Urgency of surgery				
Emergency	Ref			
Elective	1.6 (0.3-9.2)	0.7		
Type of initial surgery[¶]				
Craniotomy	Ref	0.6		
Burr hole	0.3 (0.1-3.6)			
V-P shunting	1.2 (0.1-14.4)			
Presence of co-morbidity				
Absent	Ref			
Present	2.5 (0.5-12.6)	0.4		
ICU admission				
No	Ref			
Yes	0.3 (0.1-0.9)	0.04	0.2 (0.1-0.8)	0.03
Type of Scan				
Routine	Ref			
Urgent	6.8 (1.7-27.7)	0.004	8.5 (1.9-38.1)	0.005

Duration of Hospital admission				
< 1 month	Ref	0.7		
1-2 months	0.6 (0.1-6.9)			
2-3 months	1.4 (0.4-5.3)			
3 months +	2.9 (0.4-19.8)			
Readmission after discharge from hospital				
No	Ref			
Yes	3.7 (1.0-13.8))	0.05		
Time from initial surgery to scan				
<30 days	Ref	0.5		
30-60 days	0.9 (0.2-3.8)			
60+ days	0.3 (0.1-1.9)			

4.9 Summary of results

Of the 298 neurosurgical patients reviewed, only 53 (18%) were confirmed to have had post-operative imaging studies done within 6 months of surgery. In another 28 (9%) patients, it remains unknown if they had scans at all, since the scans were requested but no scan results were documented. Most patients had a single imaging study with CT scan being the most common imaging modality. Patients who were likely to have had post-operative imaging were those with planned surgeries, those who were admitted into the ICU post-operatively and those with longer duration of hospital stay and hospital readmission after discharge. Majority of scans were done for urgent indications, with an altered state of consciousness being the most common indication for urgent scanning.

The time to imaging study was shorter for patients who had a longer duration of hospital admission and for patients who were readmitted within 6 months following cranial surgery.

Of the 53 patients with imaging studies, majority (60%) had had urgent scans for various neurological indications of whom majority (68%) had positive (pathological) findings. The most common finding was ‘expected post-surgical changes’ which was noted in 17(32%) of the scans. The proportion of patients with pathological findings did not differ by timing of the scan irrespective of the scan type (routine vs urgent).

Twenty one of 53 patients (40%) had a surgical intervention after imaging. The patients with urgent scans were more likely to have had a surgical intervention after imaging compared to patients with a routine scan requested, (53% vs. 14%.; p=0.005, C.I=95%). The time at which the postoperative scan was done did not affect the likelihood of surgical intervention after an imaging study. Majority of patients who did not have a surgical intervention after imaging (n=32, 60%) had unremarkable/non-pathologic findings on imaging study.

5.0 DISCUSSION

5.1 Introduction

Appropriate post-operative imaging should lead to increased identification of the critical findings that influence the subsequent patient management. This study set out to determine the diagnostic benefit accrued to neurosurgical patients operated between June 2011 and May 2013 at Kenyatta National Hospital (KNH) (herein thereafter referred to as the 2011-2013 cohort) who underwent postoperative radiological investigations within 6 months of surgery. We found that less than a quarter of the patients had undergone cranial imaging 6 months after surgery. Majority of the scans were CT scans done for urgent indications. The most common finding was 'expected post-surgical changes' and subsequent surgical intervention was not required in majority of cases. These results are discussed in subsequent paragraphs.

5.2 Proportion of patients that undergo postoperative imaging

Approximately 20% of neurosurgical patients are expected to develop one or another form of postoperative complication [32]. This study revealed that 18% of all patients (irrespective of pre-operative diagnosis) had a post-operative scan within 6 months of surgery. Based on this coverage, most eligible patients stood a chance to get a scan and lesions were unlikely be missed merely due to the proportion of patients accessing the service. A study in the United Kingdom, in the year 2001, reported that 22% of the patients had scans within 48 hours. Two other studies in the United States, in 2010 and 2008 reported a rate of 74% within 24 hours of surgery and 90.4% within a median time of 19.2 hours respectively. The latter study focused on patients with head injury while the former two studies had patients with various diagnoses. This variation in figures might reflect the imaging policies or preferences in place at the time the studies were carried out. However, targeting the proportion of patients at risk of neurological complications might not necessarily result in better patient outcomes. This is because non-neurological complications such as deep venous thrombosis (DVT) are common and may adversely contribute to postoperative patient outcomes. For instance: following surgery for brain neoplasms, the overall complication rate is between 9%-40%, DVT occurs in 3% - 26% while the incidence of new or worsened neurological deficits ranges from 0%-20% [3, 13, 34, 35.].

5.3 The choice of imaging modality

The most preferred imaging modality was the CT scan, which was performed in 50 (94%) of the patients. In this study, the indications for imaging were not unique among the patients who had MRI scans compared to those in patients who had CT scans. Therefore either imaging modality may have been successfully utilized. The role of MRI in the immediate post-operative period is limited by the potentially non-compatible surgical implants or patient monitoring equipment especially for patients who get admitted in ICU in the post-operative period [4].

However, MRI is rapidly becoming widely available in urban centers and may be used more frequently especially in the follow-up of tumors after resection. Intra-operative MRI is not yet available locally and the introduction of advanced applications such as perfusion studies, functional MRI and tractography are expected to increase the utility of this imaging modality.

5.4 Factors affecting chances of having a post-operative scan.

The patient's age, gender and presence of co-morbidity did not influence the chances of having a post-operative scan. While co-morbidities might be expected to increase the chances of getting a post-operative scan, this was not the case because the co-morbidities were evaluated using modalities other than cranial scans.

Although odds ratios suggest that majority of patients who had post-operative scans were neither admitted to the ICU nor readmitted to hospital within 6 months of surgery (see table 2), these two factors actually increased the chances of getting a scan. The paradox can be explained by the fact that only a small fraction of the post-surgical patients were admitted to ICU or had a hospital readmission within 6 months of surgery (19% and 7% respectively). The proportion of patients who had scans was higher among those who had these two risk factors than among those who did not. Hazard ratios demonstrated that patients who were admitted to ICU were 3.4 times ($p=0.0005$), while those who were readmitted were 5.6 times ($p<0.0001$) more likely to have scans than the rest (see table 3).

Similarly, although majority (60%) of the scans were done in patients who stayed in hospital for less than one month after surgery, the patients who remained in hospital for 1-2 months and 2-3 months were respectively 4.6 and 3.5 times more likely to have a scan, than those who were discharged within 1 month of surgery (p=0.0003). Interestingly, patients who remained in hospital for more than 3 months after surgery did *not* have a higher chance of getting scans (see figure 3). It was noted that some of the reasons for remaining in hospital beyond 3 months post-operatively were non-neurosurgical in nature, i.e. patients waiting to clear hospital bills, those who needed care for pressure sores and those awaiting placement in children's homes.

5.5 Indications for imaging

Familiarity with the appropriate indications for imaging is important because it directly determines if a scan will be requested or otherwise. While a single patient might present with multiple signs/symptoms, this study attempted to identify the features that were of concern as recorded by the attending neurosurgeon and took these to be the indications for imaging. Routine scans were typically denoted as 'check scan' in the clinical notes.

In this study, 32 (60%) of the scans were 'urgent', i.e. they were ordered when there was a specific neurological derangement to be addressed. Unlike in routine scans, 17 (53%) of the scans performed for urgent indications had findings that necessitated subsequent surgery (p=0.005, C.I=95%). This underscores the importance of clinical evaluation in determining the need for postoperative imaging. Our results are consistent with those in USA in 2010 which showed that scans done within 24hours of surgery did not predict a repeat surgery unless a prior neurological deficit had been observed. A subsequent study in USA in 2013 also showed that scans done in the absence of a neurological deficit were not likely to produce a positive finding or to result in subsequent surgical intervention [13, 38].

Minority (21; 40%) of the scans was obtained for routine follow up and their findings were less likely to necessitate subsequent surgery: only 3 (14%) of these patients ended-up having subsequent surgery. Routine imaging, especially in the immediate postoperative period has been found to be of limited value [39, 40, 41.]. Nevertheless, in patients with selected brain tumors, routine imaging is useful for early detection of asymptomatic (radiographic) tumor recurrence to allow for alternative interventions especially in clinical trials. A routine 'baseline scan' may also be preferred in these patients. The value of a routine scan will therefore depend on the purpose it is intended to serve [4, 27, 36, and 37].

5.6 Time-to-scan

The median time at which post-operative scans were obtained was 20 days, and this did not significantly vary whether there was neurological derangement or the scan was routine. A significant variation in the median time-to-scan was noted among patients who underwent emergency verses elective surgery (12 vs 23 days, $p=0.01$).

It is likely that the time at which the post-operative scans are done is conveniently designed to coincide with the first outpatient clinic visit following discharge from hospital. Because this can potentially lead to delayed detection of post-operative complications, patients should be encouraged to return to hospital sooner should they notice unexpected events. Furthermore, the need for post-operative imaging should be evaluated in each patient before they are discharged from hospital.

5.7 Factors influencing the decision to image

This study revealed that patients in an apparently poorer clinical state as evidenced by post-operative admission to the intensive care unit (ICU), longer duration of hospital stay, and hospital re-admission within 6 months of surgery were more likely to receive imaging after surgery. Other studies have also suggested certain groups of patients that are more likely to benefit from post-operative scans e.g. those with new neurological deficits, unexpected post-operative events and probably in critically ill patients in whom neurological examination might not be adequate. These patients may have experienced post-operative complications [39, 40, 41.].

The importance of identifying categories of patients that are more likely to benefit from post-operative imaging can be illustrated using Bayes' theorem of probability. This theorem can be applied to demonstrate that the probability of a diagnostic test to detect a disease is conditional, and depends on the prevalence of the disease in the population being tested. For post-operative neurosurgical patients, if we selectively scan patients with a higher tendency to harbor postoperative complications, we should expect that a higher proportion of scans will yield findings that can influence subsequent surgical decisions. This should remain true regardless of how highly sensitive and specific the scans can get [43].

The various indications for imaging are outlined below against the proportions of patients who had surgical intervention following the scans. Although the numbers of patients with specific indications might be too small for significance testing, it is clear that scans done due to a neurological deficit were more likely to result in surgical intervention.(Exception is noted of non-specified 'altered level of consciousness').

Table 6: The proportions of patients who had surgical intervention according to the indication for imaging.

General Indication for Scan	Specific Indication for Scan	Number of patients	Number of patients with Surgical Intervention After Scan	Proportion (%) of patients that benefitted from scan (i.e. underwent surgery after scan)
Urgent	**Urgent scans**	**32**	**17**	**53**
	Confusion	1	1	100
	Convulsions	4	4	100
	Fever	3	3	100
	Focal Neurological deficit	1	1	100
	Wound infection	1	1	100
	Visual disturbance	3	2	67
	Raised intra-cranial pressure	5	2	40
	Headache	3	1	33
	Altered level of consciousness	9	2	22
	Aphasia	1	0	0
	Cranial Nerve Palsy	1	0	0
Routine	**Routine follow-up**	**21**	**3**	**14**
Total		**53**	**20**	**38**

For instance, patients with convulsions, confusion and fever demonstrated a higher probability of benefitting from postoperative scans and should probably be given priority for imaging.

On the other hand, this study found patients who got admitted to the ICU to be a peculiar group: while admission to ICU was associated with *higher* chances of getting a post-operative scan (P=0.0005), it was also associated with *reduced* chances of having a subsequent surgical intervention (p=0.03, CI=95%).It has been reported that only 26% of patients admitted to ICU require active life supporting treatment while 74% are admitted for purposes of neurological monitoring, such that a large number of these patients can be successfully cared for outside the ICU [46]. At KNH, patients who have elective surgeries are more likely to be admitted to ICU compared to emergency cases (Odds ratio 4.8, 95% CI= 2.2-10.5: $p<0.0001$). This can be attributed to the fact that prior confirmation of the availability of an ICU bed is a pre-requisite for an elective surgery to take place, unlike for emergency cases. The patients who end up in ICU are therefore not uniformly critically ill and the risk of having subsequent surgery is diminished among these patients. Contrary to expectation, the neurosurgical patients that get admitted to the ICU post-operatively might constitute a category that is collectively less likely to benefit from routine scanning.

5.8 Findings on postoperative scans

Accurate interpretation of postoperative scans requires correlation between the clinical status of the patient, the purpose of the surgical procedure and the radiological findings. For instance, in order to consider a residual tumor either as a positive finding or as an expected finding, it should be clear whether the intention of the surgery was to excise part of or the entire tumor. In this study, residual tumors were considered a positive finding because they have been shown to have an impact on the life expectancy of the patient [21]. Similarly, when a patient with both hydrocephalus and a tumor undergoes ventriculoperitoneal shunt insertion, the presence of the tumor on postoperative scans might not be regarded as a positive finding. In such a patient, it may be more helpful to evaluate the position, integrity and function of the shunt.

Thirty six (68%) of the scans in this study reported a positive finding, with no statistically significant difference between the urgent (75%) and routine (57%) scans (p=0.08, see table 4). Here, 298 patients had 53 scans within 6 months. This sharply contrasts with the findings reported elsewhere, where only 4.7% of routine scans had a positive finding. In their study, 801 scans were ordered for 233 patients within 4 months, meaning that many patients had multiple scans. A commentary on the study regarded the practice as a ‘medical waste,’ implying that many of the scans may have been unnecessary. It is apparent that the probability of detecting a positive finding diminishes with an increase in the proportion of patients that are routinely scanned. This phenomenon might account for the higher proportions of positive scans seen in this study [38, 45].

The same study also noted a wide variation in the probability of reporting a clinically significant finding depending on the indication for imaging. Thus studies which exclude certain surgical procedures are bound to find different probabilities of reporting a positive scan. For example, there are studies which have excluded patients who underwent insertion of implants such as ventricular shunts and deep brain stimulators [13, 38, 44.]. Consequently, the type of post-surgical complications reported in this study might vary from findings in other similar studies because of the range of surgical procedures performed. Notably, craniectomy was very rarely performed and thus no case of extra-cranial brain herniation is reported here.

The category of ‘expected post-surgical changes’ constituted the largest (32%) group of findings and included the relatively benign lesions that did not require further consideration, for instance small pockets of pneumoencephalus. The rates of post-surgical infection (11%), sub-dural hygromas (11%) and hydrocephalus (13%) are comparable to those reported elsewhere (i.e. 13%, 17% and 11% respectively) [44].

It has been found that 88% of surgery related hematomas occur within the first 6 hours following surgery [35]. Other prospective studies in which the imaging was done within 24-48 hours after surgery have commonly reported post-operative hemorrhages. However, in this study, majority of the scans were done beyond the immediate post-operative period, and lysed hemorrhages may have been reported as post-surgical fluid collections or hygromas.

Despite the limited number of patients in this study, the proportion of patients whose indication for imaging was ‘features of raised intracranial pressure (headache, vomiting)’ or ‘altered levels of consciousness (proxy for examination change)’ who had positive findings, was fairly comparable to that in literature (40% in this study compared to 33% and 55% vs 30% respectively in a prospective study in the USA in 2011 [38].

5.9 Relationship of findings to timing of the postoperative scan

In this study, the timing of the post-operative scans did not predict the chances of detecting a positive finding on the post-operative scan, nor the chances that a repeat surgical procedure will be required. This implies that there is no specific time point that is optimal for scheduling all post-operative scans.

On the other hand, some postoperative events occur after certain periods of time and thus the timing of a post-operative scan has a bearing on the ability to demonstrate intracranial lesions [2, 18]. The ideal time for scheduling a post-operative scan is variable and depends on the lesion to be demonstrated. For instance, following tumor resection, screening for residual mass will be more accurate when the scan is performed before the onset of the potentially confusing normal enhancement at the surgical site. Conversely, recurrent tumor can only be demonstrated after a period of time and not in the immediate postoperative period [5, 17, 31, 42.].

Performing an early or immediate routine post-operative scans has been recommended because the practice should help to avoid delays in identification and management of postoperative complications [4]. It is however not clear whether all asymptomatic lesions identified on scans will invariably result in clinical deterioration sooner or later. Pre-emptive scans in asymptomatic patients may show results that might therefore result in unnecessary repeat surgeries. Although such findings on postoperative scans can be graded for severity to avoid unnecessary surgery [13], a grading system might in turn give rise to a category of patients with ‘indeterminate’ findings, who will then need further scans to evaluate progress of their lesions.

5.10 Limitations of the study

The follow up period (6 months after surgery) was short and could not adequately evaluate the pattern of findings in serial postoperative scans.

The sensitivity of the study may be affected by the fact that it included a heterogeneous group of all possible disease entities that were operated between 2011 and 2013. These conditions may have different spectra of complications which cannot be effectively evaluated together. Findings of the study would be more accurate if they focused on a specific disease entity, subject to acquisition of an adequate sample size.

We were also unable to document whether majority of patients who did not get scans were likely to have benefited from the scans. This was a retrospective review of the radiological investigations done post operatively and a scan was only regarded as beneficial if it led to surgical intervention; the benefits of avoiding unnecessary surgery due to scan results were not evaluated.

It was difficult to discuss imaging characteristics of individual pathological entities because a number of patients with tumors did not have documented histological results. The other challenge was the occurrence of more than one condition in the same patient. This was commonly observed in patients who had hydrocephalus secondary to brain tumors, or skull fractures that later developed brain abscesses. In such case post-operative complications observed may not be obviously attributed to either of the underlying pathologies.

Some patient records were missing or incomplete and this may have impacted the interpretation of our results.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Although only a small proportion (18%) of neurosurgical patients undergo post-operative imaging at KNH, this proportion should be acceptable because it approximates the proportion of patients that are expected to have the postoperative complications that need to be detected. Increasing the proportion of patients that routinely get postoperative imaging may therefore not necessarily optimize the role of the scans in managing the neurosurgical patients. Instead, groups of patients with a high risk of developing clinically significant postoperative complications should be identified and selectively targeted for imaging. This includes patients who develop convulsions, signs of infection (fever) and signs of raised intracranial pressure. Elaborate patient selection is still necessary even among those patients that get admitted to the ICU because their needs for post-operative imaging remain significantly varied.

In this study, majority (60%) of the scans were obtained for specific indications as opposed to routine follow-up. This study finds that it was appropriate to minimize the number of scans that were obtained for routine follow-up because only 14% of them had findings that were of surgical importance, unlike among the scans obtained for specific indications where 53% of them resulted in subsequent surgical intervention (p=0.005, C.I=95%).

While most scans were obtained within 3 months of surgery, no specific time can yet be recommended for postoperative imaging since the tendency to detect positive findings was similar in scans done earlier (within 1 month) as compared those done later (more than1 month) after surgery. The post-operative time at which the scan was done also failed to correlate with the chances that the findings of the scan will necessitate a repeat surgical procedure. The appropriate time for imaging should thus be guided by the indication for imaging as will be derived from diligent clinical evaluation.

6.2 Recommendations

6.2.1 To clinical care

- Diligent documentation of clinical records, including radiological reports should be routine.
- Post-operative imaging should be preferably performed in patients with specific neurological deficits. Generalizations such as imaging any patient admitted to the ICU or patients with any altered state of consciousness should be avoided, unless it can be observed that the state of consciousness is of significant concern or is worsening.

6.2.2 For policy makers

- There is need to develop and disseminate clinical guidelines for appropriate use of post-operative imaging studies in neurosurgical patients.
- Diligent, accurate and standardized documentation of clinical records should be emphasized during training of clinicians and occasionally evaluated for compliance in medical practice.
- A clear policy on the custody of the previous radiological films might be useful. Currently, some of the radiological films are archived in the x-ray registry; some are randomly stored in the neurosurgical ward while others are taken home by the patient upon discharge. Alternatively, the PACS at KNH could be upgraded so that it has capacity to store and conveniently retrieve all previous imaging studies. This will facilitate radiological follow-up of patients, teaching and research.

6.2.3 For further research

- Prospective cross-cutting multi-specialty studies are required to evaluate the benefit of imaging in all categories of post-operative patients in order to delineate which patients may benefit from scanning and the optimum time for scanning. These studies may also benefit from a longer duration of follow up and a narrower scope by focusing on patients with only one disease entity.

- A clinical evaluation of the neurological deficits among patients who did not have scans would complement this study by assessing if there are patients that may have benefitted from imaging but were missed out.

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APPENDICES

Appendix I: Data collection form

Patient number:			
Age (Y):			
Gender: *Male / Female*			
Pre-operative diagnosis:			
Type of surgical procedure:			
Date of surgery:			
Date of discharge/ death:			
Was the patient alive at the end of surgical procedure? *Yes/No*			
Was the patient admitted to intensive care unit (ICU) after surgery? *Yes / No*			
Number of hospital re-admissions during study period (6 months):			
Patient outcome at the end of study period: *Alive/dead/lost to follow-up.*			
Date of patient outcome:			
Number of post-operative scans done:		CT:	MRI:
	CT scan 1	**CT scan 2**	**CT scan 3**
Type of scan	*Urgent/ Routine*	*Urgent/ Routine*	*Urgent/ Routine*
Date of scan			
Indication for scan			
Post-operative radiological findings			
Form of radiological finding	*Persistent / Recurrent / New.*	*Persistent / Recurrent / New.*	*Persistent / Recurrent / New.*
Was there further surgery after the scan?	*Yes/No*	*Yes/No*	*Yes/No*
	MRI 1	**MRI 2**	**MRI 3**
Type of scan	*Urgent/ Routine*	*Urgent/ Routine*	*Urgent/ Routine*
Date of scan			
Indication for scan			
Post-operative radiological findings			
Form of radiological finding	*Persistent / Recurrent / New.*	*Persistent / Recurrent / New.*	*Persistent / Recurrent / New.*
Was there further surgery after the scan?	*Yes/No*	*Yes/No*	*Yes/No*

Appendix II: Time frame of the study

Activity	Action by	May 2013	Jun 2013	Jul 2013	Aug 2013	Sep 2013	Oct 2013	Nov 2013	Dec 2014	Jan 2014	Feb 2014	Mar 2014	Apr 2014	May 2014
Writing Research Proposal	Student	■	■											
Revising and Finalizing Proposal	Student & Supervisor			■	■									
Ethical Approval	KNH-ERC					■	■	■	■	■	■			
Data collection and cleaning	Student R. Assistant											■		
Data Analysis and Interpretation	Student Biostatistician												■	
Writing up	Student Supervisor													■
Dissertation submission	Student													■

Appendix III : Informed Consent Document

Title of Research: A retrospective review of findings on post-operative cranial computed tomography and magnetic resonance imaging scans at Kenyatta National Hospital (KNH).

Investigators: Principal investigator: Dr. Akanga Zebedee, Department of Diagnostic Imaging and Radiation Medicine, University of Nairobi.

Study location: Kenyatta National Hospital, Nairobi, Kenya.

Purpose of Research: To evaluate the post-operative use of CT/MRI scans among neurosurgical patients at KNH.

Description of Research: The study involves an analysis of patient records for a group of patients who underwent cranial surgery during a specific time period. These patients will be followed up for a period of 6 months and their timing of imaging study and findings visualized there of assessed. Data will be destroyed after a period of 2 years (at the end of the study).

Potential harm: There is a risk of breach of the of participants' privacy. However, study records will be de-identified, anonymized and stored securely in a password protected file.

Potential benefits: Results from this study will improve the management of patients who have undergone cranial surgery by proposing better ways of using the scans after surgery.

Confidentiality: The records will remain anonymous, access to research data will be restricted as hard copies of records will be stored in locked cabinets while soft copies will be encrypted and password protected.

Reimbursements: None

Contacts: For any concerns about the study contact Dr. Akanga Zebedee, DDIRM, University of Nairobi, P.O. Box 300197 Nairobi: Telephone Number +254722936230. Email address: zed_al@yahoo.com

Should you have any questions pertaining to your rights as a research participant, kindly contact, The Secretary to the KNH/UON Ethics Review Committee, P.O. Box20723, Nairobi.

Informed Consent Form

This study is an analysis of the findings on repeat CT/MRI scans in patients who have undergone cranial surgery at KNH. Should you agree for this review to be conducted at your facility, you will be asked to allow the researcher access to patient records at your neurosurgical, radiology and medical records departments.

All data collected from will be coded in order to protect patients' identities, if applicable. Only the research study staff will have access to the information. At the end of the study, there will be no way to link patients' names with their data (where applicable).

Your facility/institution is free to withdraw or refuse to participate at any time without consequences. Should you agree to be part of this study, please sign your name below, indicating that you have you read and understood the nature of the study, your responsibilities as a participating institution, the inconveniences associated with voluntary participation in the study and that all your questions and concerns concerning the study have been answered satisfactorily.

Name of hospital staff___________________________________

Designation ____

Signature ____

Date____

Name of Investigator _______________________________________

Signature____

Date____

Appendix IV: Data Confidentiality Agreement Form for Study Assistants.

I ……………………………………………………, being a member of the study 'A retrospective review of findings on post-operative cranial computed tomography and magnetic resonance imaging scans at Kenyatta National Hospital', may in the course my work have access to confidential information. Such information includes HIV statuses of participants of the study, personal information and any other private information that if disclosed will cause embarrassment or psychological discomfort to the said individual. It is a condition of **my involvement in this study that such information is treated in a confidential way at all** times, and that I can only use or disclose it as authorized by the lead investigator for the purpose of the study.

I further affirm that I will not inappropriately use any of the information that I have access to, nor use it for any other purpose than for the intended the study.

……………………………………..

Signature

……………………………..

Date