VACUUM DRAINS VS PASSIVE DRAINS VS NO DRAINS IN DECOMPRESSIVE CRANIECTOMIES – A RANDOMIZED CONTROLLED TRIAL ON SUBGALEAL DRAIN COMPLICATION RATES

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DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SURGERY (NEUROSURGERY)

UNIVERSITI SAINS MALAYSIA

2021

ACKNOWLEDGEMENTS

I would like to acknowledge the support from all the participating neurosurgeons and medical officers in Hospital Universiti Sains Malaysia. My gratitude to Assoc. Prof Dr. Sarimah Abdullah and Dr. Mohamad Adam Bujang for their guidance in statistical analysis.

I salute my supervisors, lecturers and superiors for their tremendous knowledge and patience in imparting their experiences. The journey to becoming a neurosurgeon is not easy but this journey would not have been possible without them.

Finally, my sincere appreciation for the support and love of my family – my parents, my beloved wife, Lim Jean Jean and my sons Roel and Noel. They have kept me going, and this dissertation writing would not have been possible without them.

PREFACE

This dissertation is written as partial fulfillment for the Master of Surgery (Neurosurgery) at Universiti Sains Malaysia. Decompressive craniectomies have become an essential basic surgical skill for neurosurgeons. Nevertheless, the choice of subgaleal drains remains solely on the discretion of the operating surgeon and practice at each center. When searching through literature, only limited studies have addressed this issue. Having experienced many complications from previous decompressive craniectomies, we decided to embark on this study to determine whether the type of subgaleal drains influences the complications rates.

TABLE OF CONTENTS **PAGE**

Title page i

Aknowledgement ii

Preface iii

Abbrevations v

Abstrak (Bahasa Malaysia) vii

Abstract (English) ix

Study protocol 1

Chapter 1: Introduction 2

Chapter 2: Literature review 4

Chapter 3: Study procedures 16

Chapter 4: Materials and methods 20

Manuscript 29

Introduction 30

Methods 31

Results 38

Discussion 50

Conclusion 58

References 59

Appendices 67

ABBREVATIONS

APTT	Activated partial thromboplastin time
CT	Computed tomography
CI	Confidence interval
DC	Decompressive craniectomy
GCS	Glasgow Coma Scale
ICB	Intracerebral bleed
INR	International normalized ratio
IVH	Intraventricular hemorrhage
MCA	Middle cerebral artery
ND	No drains
OR	Odds ratio
PCH	Post craniectomy hydrocephalus
PD	Passive drains
SAH	Subarachnoid hemorrhage
SDH	Subdural hemorrhage

SGH	Subgaleal hematoma
SPSS	Statistical Package for Social Science
TBI	Traumatic brain injury
VD	Vacuum drains

ABSTRAK

Objektif: Kraniektomi antara pembedahan yang kerap dilakukan tetapi banyak komplikasi yang boleh terjadi seperti takungan darah beku, pendarahan baru di tempat lain, dan hidrokefalus. Tiub di bawah kulit digunakan untuk mengalirkan darah keluar dan mengelakkan darah daripada bertakung selepas kraniektomi. Perincian teknik kraniektomi telah pun dikaji dengan teliti tetapi hubungan kadar komplikasi dengan jenis tiub bawah kulit tidak pernah dikaji. Oleh demikian, kajian ini bertujuan untuk menilai kadar komplikasi antara 3 jenis kumpulan tiub bawah kulit iaitu kumpulan tiub vakum, kumpulan tiub pasif dan kumpulan tanpa tiub.

Kaedah: Kajian rawak terkawal bandingan komplikasi antara 3 kumpulan tiub telah dijalankan di Hospital Universiti Sains Malaysia. Sebanyak 78 pesakit dengan pecahan 26 pesakit di setiap kumpulan berjaya dikumpul. Objektif utama ialah penentuan ketebalan takungan darah beku di bawah kulit. Antara parameter lain yang dikaji termasuk isipadu takungan darah beku di bawah kulit, komplikasi lain, kebolehan berfungsi, kadar kematian dan faktor-faktor risiko parameter tersebut.

Keputusan: Tiada perbezaan ketebalan takungan darah beku di bawah kulit antara 3 kumpulan tiub (p=0.171). Purata ketebalan takungan darah beku ialah 6.6±4.46mm, 8.6±4.14mm dan 8.3±3.81mm untuk kumpulan tiub vakum, kumpulan tiub pasif dan kumpulan tanpa tiub masing-masing. Purata isipadu ketebalan takungan darah beku juga tidak menunjukkan perbezaan (p=0.320). Namun demikian, analisis yang hanya melibatkan 49 pesakit trauma otak menunjukkan purata ketebalan takungan darah beku di bawah kulit kumpulan tiub vakum lebih rendah daripada kumpulan tiub pasif. Purata isipadu takungan darah beku di bawah kulit kumpulan tiub vakum pula lebih rendah

daripada kumpulan tanpa tiub. Kadar komplikasi pendarahan baru di tempat lain tidak berbeza antara kumpulan(p=0.647). Antara 58 pesakit yang masih hidup selepas 60 hari kraniektomi, keadaan 7(12.1%) pesakit dirumitkan hidrokefalus. Tiada perbezaan kadar hidrokefalus antara kumpulan (p=0.083). Daripada analisa univariat dan multivariat, kumpulan tiub vakum menampakkan kelebihan kebolehan berfungsi. Kadar kematian kumpulan tiub vakum juga didapati lebih rendah.

Kesimpulan: Tiada perbezaan ketara antara ketiga-tiga kumpulan dari segi kadar komplikasi dan oleh itu, penggunaan mana-mana jenis tiub bawah kulit selamat disarankan. Jenis tiub bawah kulit kumpulan vakum mungkin mempunyai kelebihan bagi pesakit trauma otak dari segi kebolehan berfungsi, kadar kematian dan takungan darah di bawah kulit.

ABSTRACT

Introduction: Subgaleal drains are generally deemed necessary for cranial surgeries including decompressive craniectomies(DC) to avoid excessive post-operative subgaleal hematoma (SGH) formation but these drains maybe associated with other complications. This study aims to assess complication rates, functional outcome and mortality in patients utilizing vacuum drains(VD), passive drains(PD) and no drains(ND).

Methods: This was a triple blinded randomized controlled trial involving 78 patients requiring DC which were equally randomized into the 3 different drain groups. The primary outcome was SGH thickness. Secondary outcomes of SGH volume, new remote hematomas, post-craniectomy hydrocephalus (PCH), modified Rankin Scale(mRS), mortality rates and their associated risk factors were studied as well.

Results: There was no difference in SGH thickness between the 3 drain types (p=0.171). The mean SGH volume and new remote hematoma rate was not significantly different (p=0.320 and p=0.647 respectively). Only 1 patient in the VD group required re-surgery to evacuate SGH. 58 patients survived at least 60 days after DC, 7 of them (12.1%) developed PCH with insignificant difference between groups(p=0.083). In the univariate and multivariate analysis, VD group had better mRS (p=0.011) and mortality rates (p=0.032). In the subgroup analysis of 49 TBI patients**,** mean SGH thickness of VD group was significantly less than PD and ND group but this did not improve outcomes (p=0.022).

Conclusion: There was no difference in SGH thickness, SGH volume, rates of PCH or new remote hematomas in all types of drain. However VD may have an advantage with regards to mRS, mortality rates, and lower SGH amounts in TBI.

Key words: subgaleal drains; subgaleal hematoma; decompressive craniectomy; complications; hydrocephalus; functional outcome; mortality

STUDY
PROTOCOL

STUDY PROTOCOL

CHAPTER 1

INTRODUCTION

Drains were appliances that form a channel to allow egress of existing or potential accumulation of body fluid, blood or pus, while allowing for gradual apposition of tissue.[1] The excessive body fluid or blood acted as a perfect medium for bacterial growth and thus promoted surgical site infection.[1–3] Therapeutic drains were accepted as necessity but prophylactic drains use were amongst the great controversies in surgery.[4,5] Drains can be divided based on their mechanism of action. Passive drains acted by the mechanism of capillary action, gravity or fluctuation of intra-cavity pressure.[5,6] Active drains were aided by active suction which could be low continuous, low intermittent or high suction drainage.[5,6]

There were concerns for routine drain usage as drains were not without complications. A few common complications include wound infections, injury to tissues, source of discomfort and pain during removal, limiting mobility and additional scarring. In 2 large prospective studies, wounds without drains had a lower infection rate than clean wounds with drains.[7,8] There was noteworthy evidence that many general surgical and obstetric procedures could be carried out safely without placement of a drain.[9,10] Evidence of benefits of drains in spinal surgery is also lacking.[11] The placement of prophylactic subgaleal drains have generally been deemed necessary for cranial surgeries to avoid post-operative subgaleal collection but has not been backed with robust scientific evidence on the advantages of its use.[12,13]

There have been emerging evidence that prophylactic VDs may not be necessary. In studies comparing complications in cranioplasty patients, Chang *et al.* showed that use of

subgaleal VD as opposed to ND, was possibly protective against postoperative SGH or collection requiring repeated operation but Sobani *et al.* found no significant difference in this outcome.[12,14]. Choi SY *et al*. showed that drains were not needed in pterional craniotomy. In their study, subgaleal drains caused a higher rate of SGH (7.9%) compared to the ND group (2.4%) and the surgical site healing process was significantly better when ND were used. [15] Guangming *et al*. also reported that a drain did not prevent formation of epidural hematomas and subgaleal CSF collection after supratentorial craniotomy. There was epidural hematoma in 12% of patients in the no drain group and 12.5% of patients in the drain group.[16] In 2020, Hamou *et al*., further added evidence that presence of subgaleal drains in supratentorial craniotomies did not affect accumulation of SGH nor operative revision.[13]

The evidence so far was mainly for craniotomies and cranioplasties and not DCs. DCs are performed by residents in an emergency setting and requires a large skin flap. These factors were deemed by some to encourage a subgaleal drain use.[13] DC were associated with many complications including subdural effusions (49%), PCH (14%), subgaleal hematomas and new remote hematomas (10.2%) but it is unclear if the type of drain influeces the rate of these complications.[17–20] Although DCs are common surgeries, there was no clear guideline on the type of subgaleal drain that should be routinely used in DC.[21–23]. We have therefore carried out a randomized control trial aimed to assess complication rates, functional outcome and mortality in patients utilizing VD, PD and ND in DC.

STUDY PROTOCOL

CHAPTER 2

LITERATURE REVIEW

2.1 Drains definition

Drains are appliances that act as a deliberate channel through which established or potential collection of pus, blood or body fluid egress to allow a gradual collapse and apposition of tissue.[1,6]

2.2 Indications of surgical drains

In general, drains have 2 broad purposes. Firstly drains are therapeutic and permits exit of unwanted gases and liquid for example in the treatment of hydrocephalus using external ventricular drains and drainage of pus from an abscess cavity.[1,24] Secondly, drains are used prophylactically to prevent post-operative complications that could arise from fluid accumulation in a wound cavity.[13,25]

2.3 History of surgical drains

To better appreciate the principals behind surgical drain use, a brief historical perspective of surgical drains and controversies surrounding it is needed. In the Hippocratic era of 400B.C., we found drainage attempts to release pus from an empyema of the chest and the drainage of ascites associated with liver disease which was still used today.[4,26] Ambroise Paré began to recognize that drains could be blocked and became aware of complications that may arise from inappropriate use of drains during the Renaissance.[4,26] Ephraim McDowell, who carried out the first successful laparotomy in a small village in Kentucky in 1809 first used the drain

prophylactically when he brought the silk suture to the surface through the abdominal wound.[4] Schroeder in 1875 stated that it was not avoidance of the peritoneal secretion that was important, but care not to infect it, and through this a new principle in surgery was born.[4,5] Prophylactic drainage of the peritoneal cavity was one of the great controversies. There were giants like Theodor Billroth who believed that drains in gastrointestinal surgery had saved many lives, others condemned it as useless if not futile.[27] Mikulicz in 1881 emphasized the importance of closing all dead spaces by careful technique, condemned any form of irrigation through tubes, and devised the gauze tampon which found its permanent place in the history of surgery. In 1891 Hunter Robb at the Johns Hopkins Hospital reported the first major bacterial study of drains. He found that nearly 50% were contaminated with microorganisms.[4] Heaton, in 1898, was the first to apply water activated suction to a sump tube.[26,28] In 1952 Raffl developed a method of continuous suction. He employed an external source of vacuum connected to the drainage tube which was open to the atmosphere mainly in radical mastectomies.[26,29] A few years later the closed continuous suction drain was brought into the marketplace. Prophylactic drain placement postoperatively had been widely practised since the mid-1800s, with the dictum of Lawson Tait 'When in doubt, drain'.[5,30] This is an unscientifically sound statement that is still upheld today particularly in cranial surgeries with little evidence on safety of subgaleal drain ommision.

2.4 Types of drains

Drains can be divided based on their mechanism of action. Passive drains act by the mechanism of capillary action, gravity or fluctuation of intra-cavity pressure. Examples are corrugated rubber drains, Penrose drains, and sump drains. Active drains

are aided by active suction which could be low continuous, low intermittent or high suction drainage. Examples are Jackson-Pratt drains, Surgivac® drains and Redivac® drains.[6,31]

Drains are also divided into tube drains, sheet drains and flat drains. Tube drains are hollow tubes brought out through a body orifice or stab wound. When they are connected to a bag, they become closed but when left alone, they remain open.[6] Sheet drains are made of gutters of parallel tubes through which fluid passes. A common example of this is the corrugated rubber drain. Flat drains are made flat with multiple perforations. The inner wall of the flat segment usually has internal "ribs" to prevent it from collapsing or kinking. [6]

The other distinction of drains are whether they are open or closed. Open drain systems empty directly to the exterior wound.[31] Overlying skin is often excoriated and infection rates are higher. Closed drain systems are connected to a closed sterile drainage bag.[31] The risk of skin excoriation and infection is less. [32,33]

Based on the materials used, there are irritant drains which induce fibrosis such as rubber drains. There are also inert drains that are non-irritative and do not provoke fibrosis such as silastic drains. [1]

2.5 Advantages of surgical drains

There is no doubt that therapeutic use of drains for drainage of unwanted fluid such as pus is undisputed. Proponents of routine prophylactic drain use believe that if excessive body fluid or blood were allowed to accumulate, there would be pressure on adjacent tissues and surgical site, causing pain and reduced perfusion leading to impaired wound healing.[24,31] The excessive body fluid or blood may act as a perfect

medium for bacterial growth and thus promote surgical site infection.[1–3] Drains also allow for early detection of anastomotic leaks or hemorrhage.[1,31]

2.6 Possible complications caused by vacuum drain usage

2.6.1 Subgaleal hematoma causing mass effect requiring another surgical evacuation of clot

The fear of developing subgaleal hematomas(SGH) was the main driving factor for routine use of vacuum drains. A systemic review by Kurland *et al* found that many studies reported on the development of new ipsilateral hematomas following DC, which included subgaleal, epidural, subdural, and/or intracerebral hematomas. Across all indications, 10.2 % (236/2297) of patients who underwent DC developed a new ipsilateral hematoma.[17] It was not specified whether the SGH caused mass effect and needed another surgery for evacuation. Nittby *et al*. in their 2016 review of cases of post-operative hematoma found that 3.9% of craniectomy operations had post operative hematoma at the site of original surgery requiring resurgery.[34] Palmer et al. described post-operative hematomas requiring surgical evacuation. The most frequent diagnosis leading to postoperative hematoma was meningioma surgery (6.2%), followed by craniotomy for trauma(3.7%), aneurysm surgery(2.6%) and intrinsic supratentorial tumors(2.2%). Postoperative hematomas were extradural in 33% and confined to the superficial wound in 11%. The overall mortality was high at 32% overall.[35] There are other reports on development of SGH after craniotomy despite having a VD placed. Holland *et al.* described 2 cases of SGH after craniotomy for aneurysm clipping.[36]

2.6.2 New remote hematomas

It is possible that negative pressure drains may exert forces on clots and destabilize them, leading to new remote hematomas. According to Huang YH *et al*, the incidence of remote extradural hematoma following decompressive hemicraniectomy for TBI was 7.9%.[37] There were two independent risk factors for remote extradural hematoma, including absence of contusional hemorrhage and presence of remote skull fracture. The negative pressure caused by the suction drain may also contribute to the development of remote extradural hematoma by creating a potential space.[15,37] In support of this, a recent 2020 randomized controlled trial found new hematomas occurred significantly more after DC when conventional rapid decompression was performed compared to a controlled decompression group.[38] The sudden high pressure negative suction by VD compared to the gradual drainage by PD would be similar in concept. Chung HJ *et al.* had 3 cases of extradural hematoma post craniotomy for tumor surgery.[39] They suggested that a sudden reduction in ICP may cause traction on the meningeal vessels, such that the negative pressure strips the dura from the inner table of the skull, causing the extradural vessel to bleed.[39] In another case report, Roth *et al*. reported new epidural hematomas and bradycardia following cranioplasty and usage of vacuum subgaleal drains.[40] Meguro *et al* illustrated a case of extradural hematoma post craniotomy and the source of the hematoma was an injured scalp artery along the route of the drainage catheter.[41] If no drains were needed, there will not be a risk of damage to vessels during blind removal of the subgaleal drain. Woo *et al.* experienced postoperative ascending transtentorial herniation and new remote hemorrhage in a patient that underwent cranioplasty after using a negative-pressure subgaleal drain.[42] Mohindra *et al.* had a case of superior sagittal sinus bleed due to negative-pressure suction drain in an infant.[43] There have even been reports of

extradural hematoma resulting from overdrainage of ventriculoperitoneal shunt insertion.[44]

2.6.3 Post-craniectomy hydrocephalus

The incidence of post-craniectomy hydrocephalus (PCH) have been reported to range from 0-88.2%.[45–48] This wide variation stems from the different study populations and criteria for PCH.[45–49] The DECRA trial reports 7/73 (9.6%) PCH and the RESCUEicp trial reported 0 cases.[50,51] It could also be possible that there are certain risk factors that have not been identified. Patients with PCH are associated with poorer outcomes.[52,53] These patients are also at higher risk of overdrainage after insertion of fix-valve shunts and therefore frequently require placement of programmable valve ventricular-peritoneal shunts which are more costly compared to fix-valve shunts.[48,54] In view of the high incidence and additional morbidity for the patients, PCH has been extensively studied. Several risk factors have been identified including large craniectomies, closer distance to midline, younger age group, more severe injury, lower Glasgow coma scale score, presence of intraventricular haemorrhage and subarachnoid haemorrhage, presence of hygromas, and duraplasty.[19,49,53,55–58]. There have also been studies that dispute that DC themselves cause hydrocephalus.[46,47]

Although DC has been associated with hydrocephalus, the exact mechanism is still elusive. There are some postulations which hint that PCH may be associated with vacuum drains. There was a report of hydrocephalus occurring in vacuum assisted closure for an open scalp wound although the authors did not think it to be associated with the vacuum effect.[59]

DC may cause “flattening” of the normally dicrotic CSF pulse wave. Arachnoid granulation function is dependent on the pressure difference between the subarachnoid space and the draining venous sinuses. Waziri *et al.* suggested that because the arachnoid granulations function as pressure-dependent one-way valves from the subarachnoid space to the draining venous sinuses, it is possible that disruption of pulsatile ICP dynamics secondary to opening the cranial vault results in decreased CSF outflow.[46,60] Kaen *et al.* describes a rebound phase and a hydrodynamic phase in the pathogenesis of interhemispheric hygromas and PCH. In the rebound phase, the brain parenchyma rebounds back from the compression, generating a suction effect and expanding the interhemispheric space.[45,61] An extension of these postulated mechanisms could mean that VDs may further decrease intracranial pressure, increase the suction effect and cause CSF egress out of the drain instead of back into the venous sinuses. This disruption, if prolonged, may then disrupt the ability of the arachnoid granulations to function optimally and contribute to formation of PCH.

Some groups have also proposed that ventricular expansion may result from a relative reduction in interstitial fluid pressure in the periventricular area leading to the formation of a ventricle-parenchymal pressure gradient or a transmantle pulse pressure gradient.[62,63] PCH pathogenesis may be linked to that of low pressure hydrocephalus. Low pressure hydrocephalus is described when hydrocephalus develops even with low intraventricular pressures. The viscoelastic theory to explain this condition states that if the brain has high compliance, it would be prone to develop low pressure hydrocephalus. Brain compliance increases when there is injury to the brain parenchyma or when there is reduction in extracellular fluid volume. Vacuum drains may contribute to reduction in extracellular fluid volume.[64,65] Another way to explain

low pressure hydrocephalus is by deformation hysteresis concept. This concept states that initial ventricular dilatation may cause the ventricles to remain dilated even at low intraventricular pressure when the initial insult has resolved. It is then possible that the negative pressure generated by the vacuum drains may initiate this process and cause PCH.[64,65] Nonetheless, the frequent use of vacuum drains in decompressive craniectomies may have a part to play in the pathophysiology and this needs to be explored.

2.6.4 Unexpected bradycardia and hypotension

Multiple reports illustrate these events when connecting the drains to negative pressure. Yadav *et al* attributes this to sudden intracranial hypotension or the trigeminocardiac reflex. The trigeminocardiac reflex is described as the sudden onset of parasympathetic activity, sympathetic hypotension, apnoea, or gastric hypermotility during central or peripheral stimulation of any of the sensory branches of the trigeminal nerve.[66,67]

Another mechanism by which a decrease in intracranial pressure in the supratentorial compartment can produce bradycardia and even asystole is reverse brain herniation and stretching of the brainstem. Van Roost *et al*. reported harmful upward herniation syndrome and pseudohypoxic brain swelling after uneventful brain surgery, likely related to suction drainage.[42,68]

This may happen more often than is reported due to lack of awareness. If undetected, patient may die from this complication.

2.7 Studies on subgaleal drains that have been done

There have been emerging evidence that prophylactic VDs may not be necessary. The evidence so far is mainly for craniotomies and cranioplasties and there is yet any data on drain usage for DC (Table 1).

In studies comparing complications in cranioplasty patients, Chang *et al.* showed that use of subgaleal vacuum drains as opposed to no drains, was possibly protective against postoperative SGH or collection requiring repeated operation but Sobani *et al.* found no significant difference in this outcome.[12,14]. Choi SY *et al*. showed that drains were not needed in pterional craniotomy. In their study, subgaleal drains caused a higher rate of SGH (7.9%) compared to the ND group (2.4%) and the surgical site healing process was significantly better when no drains were used. [15] This result is surprising as one would logically think that suction decreases the amount of remaining subgaleal blood. A possible explanation for this retrosepctive study was that the surgeons of the ND group were presumed to pay more attention to hemostasis compared to the VD group. Guangming *et al*. also reported that a drain did not prevent formation of epidural hematomas and subgaleal CSF collection after supratentorial craniotomy. There was epidural hematoma in 12% of patients in the no drain group and 12.5% of patients in the drain group.[16] In 2020, Hamou *et al*., further added evidence that presence of subgaleal drains in supratentorial craniotomies did not affect accumulation of SGH nor operative revision.[13]

2.8 Weakness of studies on subgaleal drains that have been done

There were a few weaknesses of earlier studies that we have improved on. First of all, no randomized controlled study on subgaleal drains have been done before and majority of them are retrospective studies that were prone to selection bias and missing data. At most, such studies are only able to provide data on the safety of nuances on subgaleal drain choice

between surgeons. Secondly, the procedures studied were cranioplasties and craniotomies.[12–16] These surgeries were very heterogenous in terms of underlying diagnosis, skin flap size, location and post op care. If there are no attempts to standardize the surgical procedure performed, there would be many confounders that may influence the results obtained. No attempts have been previously made to determine if vacuum drains may be directly linked to PCH, new remote hematomas, functional outcome or mortality. Furthermore, previous studies did not study SGH amount as a continuous data and did not study whether SGH amount could be linked to poorer outcomes.

Table 1. Summary of all 5 studies on subgaleal drains whereby all studies showed no significant advantage in usage of drains to prevent subgaleal hematoma

Study	Design	N (number)	Results
Guangming *et al*., 2009[16]	Prospective observational on patients undergoing supratentorial craniotomy for epilepsy surgery Divided into 2 groups based on even and odd dates of craniotomy	Total: 342 166 no drain 176 drain	p=0.952 20 epidural hematoma in no drain group 22 epidural hematoma in drain group
Chang *et al*., 2010[12]	Retrospective analysis of complications in cranioplasty patients(subdural or subgaleal fluid collections or hematomas requiring repeated operations, infections, seizures, and sunken bone flap)	Total: 212 128 no drain 84 drain	20% complications in no drain group vs 11% in drain group Univariate p=0.069 Multivariate p=0.016
Sobani *et al.*, 2011[14]	Retrospective analysis of complications in cranioplasty patients	Total: 96 69 no drain 27 drain	1 patient developed epidural hematoma (not mentioned which group) 39% complications in no drain group vs 26% in drain group. p=not significant(not mentioned exact value)
Choi *et al*., 2015[15]	Retrospective analysis of patients undergoing pterional craniotomy for aneurysms	Total: 607 333 no drain 274 drain	2.4% subgaleal hematoma in no drain 7.9% subgaleal hematoma in drain group p=0.02
Hamou *et al*.,2020[13]	Prospective analysis of patients undergoing supratentorial craniotomy	Total: 150 87 no drain 63 drain	34.5% early subgaleal swelling in no drain group 39.7% early subgaleal swelling in drain group p=not significant(not mentioned exact value)

2.8 Decompressive craniectomies

Of all the cranial surgeries, the most commonly performed surgery is DC. This surgery has been an increasingly common surgical procedure for the neurosurgical community as there is clear evidence from numerous studies that support DC as a life-saving surgical procedure in TBI, malignant MCA infarction and spontaneous ICB.[50,69,70] The first scientific reference and description of an hemicraniectomy was reported in 1896 by Charles Adrien Marcotte in his graduation thesis in Medicine and Surgery.[71,72] The use of DC for patients with raised intracranial pressure following TBI was firstly reported by Kocher in 1901. He advocates the use of DC, as soon as possible, in all cases of intracranial hypertension.[71,72]

Though many studies have shown long-term beneficial effects after DC, it is still regarded the last line of treatment. Long-term, deleterious neurocognitive, and psychosocial effects resulting in poor quality of life, and economical burden are well known.[20] DCs have been associated with many complications including subdural effusions (49%), PCH (14%), subgaleal hematomas and new remote hematomas (10.2%).[17–20] These complications may just be due to the surgery itself. But it may still be possible that these complications are worsened or arise solely due to the routine use of the VD.[13]

As the utility of DC increases, efforts should be made to reduce the complications related to it. Studies have been done to optimize and standardize the technique of DC but the necessity to use the VDs and the possible contribution that these drains may have to the complications of DCs have been overlooked so far. It is striking that these technical notes did not mention on the choice of subgaleal drain that should be routinely used.[21–23,73]

STUDY PROTOCOL

CHAPTER 3

STUDY PROCEDURES

3.1 Problem statements

Usage of subgaleal drains for DCs have been the usual practice so far to prevent SGH collection. However, this practice is not backed by any strong evidence that these drains actually deter SGH collection. On top of that, these vacuum drains may itself be causing complications that have not been discovered before. The usual complications associated with prophylactic vacuum drains are surgical site infections and wound breakdown. There are other complications that could be attributed to the routine usage of prophylactic vacuum drains. These include new remote intracranial hematomas, PCH and bradycardia or hypotension during the skin closure stage of craniectomy.[17,20] Furthermore, previous studies on subgaleal drains have been mainly retrospective and observational. In this aspect, many confounders may influence the results.

3.2 Study rationales

By conducting this study, it would show early evidence as to whether prophylactic vacuum drains or passive drains should be routinely used for every decompressive craniectomy. If these drains are not needed the advantages include savings in terms of cost of surgery, reduction of discomfort and pain during removal of drain. Definitely, the greatest benefit would be reduction of complications of decompressive craniectomy if an association is found between vacuum drains and the complications listed earlier.

3.3 Research Questions

1. Is there a difference in mean maximum thickness of subgaleal hematoma after decompressive craniectomy for vacuum drains, passive drains and no drains group?

2. Is there a difference in rate of new remote hematomas after decompressive craniectomy for vacuum drains, passive drains and no drains group?

3. Is there a difference in the rate of PCH after decompressive craniectomy for vacuum drains, passive drains and no drains group?

4. Is there a difference in the rate of unexpected bradycardia/hypotension after decompressive craniectomy for vacuum drains, passive drains and no drains group?

5. Is there a difference in functional outcomes of patients at 6 months after decompressive craniectomy for vacuum drains, passive drains and no drains group?

6. Is there a difference in mortality rate of patients at 6 months after decompressive craniectomy for vacuum drains, passive drains and no drains group?

7. What are the risk factors for higher subgaleal hematoma thickness and volume?

8. What are the risk factors for post-craniectomy hydrocephalus after decompressive craniectomy?

9. What are the risk factors for poor outcome and mortality after decompressive craniectomy?

3.3 General Objective

The main purpose of this study is to compare the complication rates of vacuum drains, passive drains and no drains after decompressive craniectomy

3.4 Primary Specific Objective:

1. To determine the mean maximum thickness of subgaleal hematomas for vacuum drains, passive drains and no drains after decompressive craniectomy

3.5 Secondary Specific Objectives:

1. To determine subgaleal hematoma volume for vacuum drains, passive drains and no drains after decompressive craniectomy

2. To determine the rates of new remote hematomas for vacuum drains, passive drains and no drains after decompressive craniectomy

3. To determine the rates of post craniectomy hydrocephalus for vacuum drains, passive drains and no drains after decompressive craniectomy

4. To determine the rates of unexpected bradycardia/hypotension for vacuum drains, passive drains and no drains after decompressive craniectomy

5. To determine functional outcomes of patients at 6 months for vacuum drains, passive drains and no drains after decompressive craniectomy

6. To determine mortality rate of patients at 6 months for vacuum drains, passive drains and no drains after decompressive craniectomy

7. To determine the risk factors for higher subgaleal hematoma thickness and volume after decompressive craniectomy

8. To determine the risk factors for post craniectomy hydrocephalus after decompressive craniectomy

9. To determine risk factors for poor functional outcome and mortality after decompressive craniectomy

STUDY PROTOCOL

CHAPTER 4

MATERIALS AND METHODS

4.1 Research Design

This was a non-inferiority randomized control trial to evaluate the complications rates, functional outcome and mortality rates of the different subgaleal drain groups. The study has been approved by the ethics committee (USM/JEPeM/18070350). The trial protocol was registered under ClinicalTrials.gov (NCT03777774). Participants were randomized to one of the 3 parallel groups in a ratio of 1:1:1. This was a triple blinded study. (surgeon,participant, assesor for primary objective)

4.2 Research Location and Duration

This study was performed at a tertiary hospital with well established neurosurgery services which is Hospital Universiti Sains Malaysia. The duration of study was for one-and-half years spanning from January 2019 till June 2020.

4.3 Inclusion criteria

1. Age : 12 - 80 years old (Head circumference reaches approximately 90% of the adult size at 3 years and 95% at 5 years of age)[74]
2. Patients with indication for decompressive craniectomy (post-traumatic intracranial bleeds, spontaneous intracranial bleeds and malignant middle cerebral artery territory infarction)
3. Written informed consent by legal representative of patient

4.4 Exclusion criteria

1. History of recent antiplatelet or anticoagulant use in the past 7 days
2. Patients with evidence of coagulopathy or thrombocytopenia or urea >20mmol/L
3. Presence of hydrocephalus preoperatively

4.5 Sample size and sampling

This study uses purposive sampling. All patients admitted with indication for decompressive craniectomy and fullfills the inclusion and exclusion criteria will be randomized. There have been no studies so far with data regarding the mean thickness values of SGH in patients after decompressive craniectomy. Calculation by ANOVA: Fixed effects, omnibus, one-way was done using the G. Power Statistical software version 3.1.9.2. Taking the effect size f as 0.4, alpha 0.05, power of 0.8, the total sample size is 66 patients. Taking into account a 10% dropout rate, a total of 72 patients are needed with 24 patients in each arm.

Formulas

This calculator uses the following formulas to compute sample size and power, respectively:

$$n = (p_A(1-p_A) + p_B(1-p_B)) \left(\frac{z_{1-\alpha/(2\tau)} + z_{1-\beta}}{p_A - p_B} \right)^2$$

$$1-\beta = \Phi\left(z - z_{1-\alpha/(2\tau)}\right) + \Phi\left(-z - z_{1-\alpha/(2\tau)}\right) \quad , \quad z = \frac{p_A - p_B}{\sqrt{\frac{p_A(1-p_A)}{n} + \frac{p_B(1-p_B)}{n}}}$$

where

n is sample size
Φ is the standard Normal distribution function
Φ^{-1} is the standard Normal quantile function
α is Type I error
τ is the number of comparisons to be made
β is Type II error, meaning $1-\beta$ is power

4.6 Method of research

4.6.1 Procedure during surgery

All DC were performed by senior residents supervised by the attending surgeons. The large fronto-temporoparietal craniectomies were performed in accordance to recommended techniques.[21,22] All DCs were performed in the operating room using a laminar air flow system. The patients were placed supine position with head turned to contralateral side. The sagittal angle of head were 0° to 15° horizontal to the floor. To prepare the scalp for incision, the whole scalp of each patient was shaved, prepared by iodine derivatives. A large reverse question mark shape incision was made from the midline anterior to the coronal suture, posterior 5cm behind the ear, and to the root of the zygoma. The midline was clearly marked and the craniectomy performed. The bone flap was planned to be around 15 cm in anteroposterior diameter. The craniectomy extends down toward the floor of the middle cranial fossa by roungering the squamous temporal bone to provide adequate decompression. Duratomy and duraplasty were performed using harvested pericranium in a non-water tight manner. Method of duratomy was left to the discretion of the surgeon. The 2-dimensional area of the bone flap was estimated by using the longest diameter (D)×diameter perpendicular to D (d)×π/4. Block randomization with assignment groups concealed within envelope were opened just after surgery is completed to avoid surgeon bias. Randomization was done in blocks of 6 where each block contained 2 cards of each group. This was to ensure equal representation in a 1:1:1 ratio for each group during recruitment. The 3 groups were, patients with subgaleal VD, patients with subgaleal PD and patients with ND.

The placement of subgaleal drains in the VD group, PD group and ND group were standardised where the tip of the full length drain overlied the frontal lobe and the rest of the drain will overlie the temporal lobe and placed underneath the

temporalis muscle flap. The drains were brought out through a separate stab incision towards the occipital region and attached to a standardized closed suction drain system (3.2 mm in outer diameter, 10 French, round and transparent polyvinyl chloride tube with a 400 mL Redon bottle spring evacuator chamber; Hilfsmittel, CoMorde Medical, Malaysia; Figure 1). For those patients under the PD group, the drains were connected to the same drain system but the vacuum effect would be released and placed at bed level. For patients under the ND group, drains were placed but were clamped till they are removed. This allows for surgeon blinding and acts as a safety measure where the drain may be unclamped to allow for SGH drainage if there is significant mass effect compressing the brain. The surgical sites for patients of all groups were closed in a simillar manner using absorbable braided sutures for the galeal closure and staples for the skin. Subsequent care followed clinical practice guidelines for MCA infarct, traumatic brain injury and spontaneous ICB.[70,75–77] Decision for external ventricular drains or intraparenchymal monitors were left to the discretion of the neurosurgeon. During skin closure, the anaesthesiology team will be asked to inform if there is any sudden unexpected bradycardia or hypotension.

Figure 1. Closed suction drain system used for this study

4.6.2 Post-operative monitoring and follow up

All patients were monitored in our high dependency units for significant SGH. The surgical site and dressing were inspected daily in all patients till sutures were removed. Total amount of drainage was recorded and drains were removed on the second postoperative day. Initial intracranial pathology characterization would be obtained from the last computed tomography (CT) brain before DC. CT brains with 6mm slice thickness were done routinely on the first postoperative day (24 +/- 12 hours). SGH thickness, SGH volume, nearest distance of craniectomy to midline, extracranial brain herniation and new remote hematomas were obtained from this CT brain by 2 different investigators who were not aware of the randomization. If there is clinical suspicion of hydrocephalus or SGH a CT brain will be repeated. Patients were seen in the clinic after discharge for detection of complications and for determining 6 month functional status according to the modified Rankin Scale (mRS).

4.7 Definitions

4.7.1 Subgaleal hematoma

In this study, a postoperative surgical site SGH was defined as extra-axial blood collection underneath the skin flap on CT brain.[78] The maximum thickness of SGH was measured on the axial cut of the CT brain. SGH volume was estimated by assuming that the SGH is half an ellipsoid using the formula (Figure 2):

$$\text{Volume of subgaleal hematoma} = \frac{\text{width} \times \text{length} \times \text{height}}{2}$$

The longest SGH slice was identified, and then the length and maximum width of the hematoma in this slice was measured. The height is taken as the number of counted slices with the SGH seen multiplied by the slice thickness of 6mm. This formula is a