INTRACRANIAL VOLUME POST CRANIAL EXPANSION SURGERY USING 3D CT SCAN IMAGING IN CHILDREN WITH CRANIOSYNOSTOSIS

DR SHUKRIYAH BINTI SULONG

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LIST OF ABBREVIATIONS

Abbreviation	Description
1. 3D CT	3Dimension Computed tomography
2. FOA	Fronto-orbital Advancement
3. HKL	Hospital Kuala Lumpur
4. ICP	Intracranial Pressure
5. ICV	Intracranial Volume
6. ROI	Region of Interest

ABSTRAK

Latar belakang: Kraniosinostosis adalah suatu kelainan kongenital yang menyebabkan tulang tengkorak bercantum secara pramatang. Pembedahan *cranial expansion* terdiri daripada *cranial vault reshaping* dengan atau tanpa *fronto-orbital advancement* dilakukan untuk memperbaiki tengkorak ke bentuk yang lebih normal dan untuk menambahkan jumlah isipadu intrakranial. Oleh itu, ianya penting untuk menilai perubahan jumlah isipadu intrakranial selepas pembedahan dan kesan daripada pembedahan secara klinikal dan radiologikal.

Matlamat: Kajian ini dilakukan untuk menilai isipadu intrakranial pada *primary* kraniosinotosis selepas pembedahan *cranial vault reshaping* dengan atau tanpa *fronto-orbital advancement* dan membuat perbandingan di antara kumpulan syndromik dan bukan syndromik. (2) untuk menentukan faktor yang berkaitan dengan perubahan yang ketara dalam isipadu intracranial selepas pembedahan dan (3) untuk melihat perbaikan kesan *copper beaten* dan peningkatan perkembangan otak selepas pembedahan.

Kaedah: Satu pemerhatian kajian prospektif untuk semua pesakit kraniosinostosis yang menjalani pembedahan *cranial vault reshaping* dengan atau tanpa *fronto-orbital advancement* di Hospital Kuala Lumpur dari Januari 2017 hingga Jun 2018. Jumlah isipadu sebelum dan selepas pembedahan diukur dengan menggunakan pengimejan CT imbasan otak 3 dimensi. Data demografi, penemuan klinikal dan radiologikal dikenalpasti dan dianalisa.

Keputusan: 14 kes (6 lelaki dan 8 perempuan) dengan 28 imbasan CT otak 3 dimensi dikenal pasti. Purata umur semua pesakit adalah 23 bulan. Pesakit terdiri daripada 7

syndromic synostosis (4 pesakit *Crouzon syndrome* dan 3 pesakit *Apert syndrome*). Purata jumlah isipadu intrakranial sebelum pembedahan adalah 880 mL (linkungan 641 mL – 1385 mL). Sementara purata jumlah isipadu intrakranial selepas pembedahan adalah 1081 mL (lingkungan 811 mL – 1385 mL). Perbezaannya adalah 201 mL, signifikan secara statistik (P<0.001). Secara perbandingan, jumlah pertambahan isipadu intrakranial untuk *syndromic synostosis* adalah 282 mL. Manakala untuk *non-syndromic synostosis* adalah 120 mL. Perbezaannya adalah signifikan secara statistic (P<0.004). Ujian Mc Nemar digunakan untuk menganalisis kesan selepas pembedahan pada pesakit yang sama. 3 bulan selepas pembedahan, kesan *copper beaten* yang wujud sebelum pembedahan masih dapat dilihat pada CT imbasan otak 3 dimensi di mana ia tidak signifikan secara statistik (P>1.0). Manakala, 2 pesakit yang megalami kelewatan perkembanagan otak sebelum pembedahan tidak menunjukkan perbaikan ketika pnilaian pada 3 bulan selepas pembedahan di mana ia tidak signifikan secara statistik (P>1.0). Maka, tidada perbaikan secara signifikan untuk kesan *copper beaten* dan kelewatan perkembangan otak dalam kajian ini.

Kesimpulan: Pembedahan dalam pesakit kraniosynostosis meningkatkan jumlah isipadu intrakranial selain ia memperbaiki bentuk kepala. Daripada kajian ini, pertambahan isipadu intrakranial untuk pesakit *syndromic synostosis* lebih banyak berbanding *non-syndromic synostosis*.

ABSTRACT

Background: Craniosynostosis is a congenital defect that cause one or more suture to fuse prematurely. Cranial expansion surgery which consist of cranial vault reshaping with or without fronto-orbital advancement (FOA) is done to correct the skull to a more normal shape of the head as well as to increase the intracranial volume. Therefore, it is important to evaluate the changes of intracranial volume (ICV) after the surgery and the effect of surgery both clinically and radiologically.

Objective: This study is to (1) evaluate the ICV in primary craniosynostosis patients after the cranial vault reshaping with or without fronto-orbital advancement and to compare between syndromic and non-syndromic synostosis group, (2) to determine factors that associated with significant changes in the ICV postoperative, and (3) to evaluate the resolution of copper beaten sign and improvement in neurodevelopment after the surgery.

Method: A prospective observational study of all primary craniosynostosis patients who underwent operation cranial vault reshaping with or without FOA in Hospital Kuala Lumpur from January 2017 until Jun 2018. The ICV preoperative and postoperative was measured using the 3D CT imaging and analysed. The demographic data, clinical and radiological findings was identified and analysed.

Result: 14 cases (6 males and 8 females) with 28 3D CT scan were identified. The mean age of patients was 23 months. The patients were 7 syndromic synostosis (4 Crouzon syndrome and 3 Apert syndrome) and 7 were non-syndromic synostosis. The mean preoperative ICV was 880 mL (range, 641-1234 mL) while the mean postoperative ICV

was 1081 mL (range,811-1385 mL) The difference was 201 mL which was statistically significant (P<0.001). In comparison, the mean volume increment for syndromic synostosis and non-syndromic synostosis were 282 mL and 120 mL respectively. The difference was statistically significant (P<0.004). Mc Nemar's test was used to analyse pre and post-operative changes within the same patients. At 3 months post-surgery, all 13 patients with copper beaten sign pre-operatively did not show complete resolution on 3D CT imaging. Therefore the p-value was insignificant (P>1.0). While 2 patients with neurodevelopmental delay pre-operatively showed no improvement during assessment at 3 months post-surgery. Again the p-value was insignificant (P>1.0). Hence, there were no significant resolution in copper beaten sign and improvement in neurodevelopmental delay in this study.

Conclusion: Surgery in craniosynostosis patients increases the intracranial volume besides it improves the shape of the head. From this study, the syndromic synostosis had better increment of intracranial volume compared to non-syndromic synostosis.

Keywords: *Craniosynostosis, Intracranial volume, 3D CT scan, Cranial vault reshaping, Fronto-orbital advancement*

1. INTRODUCTION AND LITERATURE REVIEW

Craniosynostosis is a condition that is characterized by the premature fusion of one or more of the cranial sutures [1]. The cranial sutures separates the skull bone plates and allow rapid growth of the skull to accommodate growing brain in the first 2 year of life. Thereafter, the process of oppositional growth and internal absorption of the skull is the major process by which skull increase in size and reaching adult size between 6 and 10 years of age. The major sutures are the metopic suture which separates two frontal bones, the sagittal suture which separate the two parietal bones, the coronal suture where the parietal and frontal bone meet and the lambdoid suture where the parietal and occipital bone meet [2].

The incidence of craniosynostosis is about 1 in 2100 to 1 in 2500 births [1, 3]. Around 60% of all craniosynostosis are non-syndromic type, while 40% are syndromic type. In the non-syndromic synostosis, the affected sutures are sagittal (40-55%), coronal (20-25%), metopic (5-15%) and lambdoid (< 5%) sutures [4]. For the syndromic craniosynostosis, the Crouzon syndrome is the most frequent, followed by Apert syndrome and Pfeiffer syndrome [5, 6]. The prevalence of Crouzon syndrome is 1 in 25 000 live births, while Apert syndrome and Pfeiffer syndrome are 1 in 100 000 live births [6].

The premature fusion will cause restriction of skull growth during development, leading to skull shape deformity. This will disturb the normal brain growth and can cause the elevation of intracranial pressure (ICP). Elevation in ICP is more common in syndromic cases or multiple suture synostosis about 30 to 40% compared to single suture synostosis around 15-20% [7, 8]. In syndromic patients, this increase of ICP is related to multifactorial cause which includes intracranial venous obstruction, hydrocephalus and upper airway obstruction [9, 10]. Meanwhile, in non-syndromic type, the risk of elevation

of ICP depend on the number of affected sutures [9]. The increased intracranial pressure appears to be low grade, intermittent and chronic. Because of the pressure is low grade, clinical symptoms are subtle or absent in most cases [11]. Patient with increased ICP may present with headache, nausea, vomiting and irritability. Headache is commonly occur in patients with multiple suture synostosis and less frequent in patients with single suture synostosis.

Chronic intracranial hypertension can also lead to neuropsychiatric disorder ranging from mild behavioural disturbances to overt mental retardation. Craniosynostosis patients are associated with three- to fivefold increase in risk for cognitive disabilities in about 30-40% of cases [12]. Mild impairment in cognitive and motor function have been seen in patient with single suture synostosis [13, 14]. It is more evident at school- age and is reported up to 35%. These result support for neurodevelopmental screening in young children with single synostosis [13]. Meanwhile the neurodevelopmental delay is worse in syndromic patients with mental and motor scores are moderate delay [15].

The diagnosis of craniosynostosis is based on physical examination and radiological findings. Clinically, patient will have abnormal shape of the head in the first year of life. The shape of head can be scaphocephaly, brachycephaly, plagiocephaly, trigonocephaly or dolichocephaly [2]. Scaphocephaly occurs due to premature fusion of sagittal suture that lead to an elongated head. On the other hand, coronal synostosis can be unilateral or bilateral. Unilateral coronal synostosis leads to anterior plagiocephaly which patients will have ipsilateral flattening of the forehead and compensatory contralateral frontal bossing. Bilateral craniosynostosis will result in a brachycephalic deformity. While in trigonocephaly, the metopic suture will premature fuse that cause a triangular keel-shaped head. Finally, the lambdoid synostosis which is rare will lead to posterior plagiocephaly.

In the syndromic synostosis, they will have craniofacial and limb/digit abnormalities. In Crouzon syndrome, patient will have combination of exorbitism, flattened malar region and beaked nose. However, the severity of facial deformity is milder than Apert syndrome. Crouzon syndrome has normal intelligence, hands and feet in opposition to the Apert syndrome. While in Apert syndrome, patients will have syndactyly which is the main characteristic features in this syndrome. Facial manifestation include a flat forehead, proptosis, hypertelorism and low-set ears. About 40-70% will have learning disability requiring special education. In Pfeiffer syndrome, the characteristic features are broad and radially deviated thumb or big toe [16].

Syndromic synostosis is usually associated with midface hypoplasia. This will cause narrowed upper airway producing obstructive sleep apnea syndrome. Typically, the incidence for airway compromise can be increase with age as the mid facial hypoplasia become more progressive. Besides, the abnormal proptotic position of the globe relative to the orbital rim will increase the risk of exposure keratitis leading to corneal ulcer and possibility of vision loss [17]. Brain abnormalities such as hydrocephalus and Chiari 1 malformation are more common seen in this group [3]. The incidence of hydrocephalus varies according to the number of affected sutures and type of craniosynostosis. About 0.28% of non-syndromic patient presented with hydrocephalus that require shunt insertion and the incidence increase to 12% in syndromic patient [18]. Hydrocephalus in craniosynostosis can occur due to either CSF flow obstruction or impaired CSF absorption which is related to the deformity of the skull or to coincidental disorder independent from craniosynsostosis.

Chiari malformation occur due to overcrowding in the posterior cranial fossa because of underdeveloped occipital bone that secondarily induce a downward herniation of the brain. Patients with syndromic synostosis are more frequently affected because it

involves more sutures and consequently has high possibility to affect lambdoid suture. The incidence of Chiari malformation is about 70% in Crouzon syndrome, 50% in Pteiffer syndrome and is not common in Apert syndrome. In syndromic synostosis, Chiari malformation has association with the hydrocephalus as high as 88% of the patients [18].

Different technique is used in the diagnosis of craniosynostosis which include radiography, CT imaging and MRI imaging. Plain film can help in diagnosis of both primary and secondary sign of craniosynostosis. Primary signs are absence of sutures, bony bridging and suture sclerosis. While the secondary signs include fingerprinting and copper beaten sign which may indicate raised of ICP [19]. The advantage of CT is the ability to assess the brain as well as the skull and sutures. From the CT imaging, the brain abnormality such as hydrocephalus and mid facial abnormalities can be assessed [20]. On the other hand, MRI imaging can help in the assessment of hindbrain herniation which is more common in syndromic synostosis. A computed tomography (CT) scanning and three-dimensional reconstruction has become the standard preoperative diagnostic in craniosynostosis. It is superior to conventional plain-film radiography and CT without 3D [21].

The surgical correction consist of cranial vault expansion and FOA [22]. Surgery usually is performed between age of 6 months and 2 years (1). The aim of surgical treatment is to increase the intracranial volume and to correct the skull abnormality. It is reported that surgery is associated with improvement in motor score in patient with neurodevelopmental delay for single suture synostosis patients [23]. While earlier surgical treatment give better long-term outcome in intelligence quotient and academic achievement in patient with sagittal suture synostosis [24]. The complication of surgery include moderate amount of blood loss during surgery, dural tear, subcutaneous hematoma, and infection [25]. The mortality has been reported to be around 0.1-2.2 %

[26]. The syndromic and multiple suture synostosis is associated with increased risk of surgical complication. This could be due to complex cranial remodelling surgery or difficulty in bone dissection which contribute to longer operations [27].

2. STUDY PROTOCOL

Objective

General objective:

1) To study the difference ICV pre- and post-operative in craniosynostosis patients and to compare the difference increment of ICV in syndromic synostosis and non-syndromic synostosis.

Secondary objective:

1) To study the resolution of copper beaten sign and improvement of neurodevelopment after the surgery.
2) To assess the inter-rater agreement in measuring ICV.

Research type

This is an observational prospective study where patients who had primary craniosynostosis and underwent operation cranial vault reshaping with or without fronto-orbital advancement in Hospital Kuala Lumpur from January 2017 to Jun 2018 who fulfilled the inclusion criteria were enrolled.

Inclusion criteria

1. All cases of primary craniosynostosis (syndromic or non-syndromic) that underwent operation cranial vault reshaping between January 2017 and Jun 2018
2. All cases are paediatric age group (up to 12 years old)
3. All types of craniosynostosis (single suture or more)
4. Pre-operative CTB 3D done within 2 months prior to surgery
5. Surgery done in Hospital Kuala Lumpur
6. Patients follow up for at least 3 months or more
7. All CT 3D reconstruction with 4mm slices, readable in DICOM

Exclusion criteria

1. Patient that underwent re-surgery
2. Patient above 12 years old
3. Secondary craniosynostosis (positional or loss of brain volume)
4. Patients lost to follow up
5. CT 3D reconstruction without soft copy

Withdrawal criteria

Nil

Sample Size

The sample size was calculated based on paired t-test analysis. A sample size of 15 patients required to detect 290 ml changes of intracranial volume pre and post-operation at power 80% and 0.05 significant level with 10% dropout.

Research duration and timelines

This study will be conducted over the period of 18 months. Data of patient from January 2017 to Jun 2018 will be collected.

Stage 1 – review of medical report (4-6 months)

Stage 2 - data collection and data analysis (4-6 months)

Stage 3 - presentation and publication (4-6 months)

Statistical analysis plan

Data entry and descriptive analysis were performed using SPSS program for windows version 22. The demography was expressed in the table forms using the mean and standard deviation (SD) for numerical variables and numbers and percentages for categorical variables. To study the difference ICV pre-and post-operative, paired t-test was used and independent t-test was used to compare the difference increment of ICV in syndromic synostosis and non-syndromic synostosis. ANOVA was used to determine

factors that associated with significant changes in intracranial volume. To determine the resolution of copper beaten sign and improvement of neurodevelopmental delay post-operation, Mc Nemar test was used. The statistical significance was considered when P <0.05. To measure the inter-rater agreement between 2 observers, the intraclass correlation coefficient was used. The value ICC > 0.8 was considered as excellent correlation.

Ethics of Research

This study needs the NMREC approval from MOH via NMR. All data taken are strictly private and confidential and will be used for this study purpose only. Personal identifiers will not be collected. Patient will not be informed of the study findings. The template of study will undergo "storage and destroy" once it is completed.

Privacy and confidentiality

Subject's name will be kept on a password-protected database and will only be linked with study identification number of this research. This means, only identification number instead of patient identifiers will be used on subject data sheets, and all data entered into a computer which is password-protected. On completion of the study, data in the computer will be copied to CDs and subsequently deleted. All CDs or hardcopy data will be kept in a locked office of the researchers and maintained for a minimum of three years after the completion of the study. The CDs and data will be destroyed after that period of storage. Subjects will not be allowed to view their personal study data, as the data will be consolidated into the database.

INTRACRANIAL VOLUME POST CRANIAL EXPANSION SURGERY USING 3D CT SCAN IMAGING IN CHILDREN WITH CRANIOSYNOSTOSIS

Shukriyah Sulong [1,2], Alias Azmi [1], Fadzlishah Johanabas [1], Johari Yap [3], Badrishah Idris [2]

1. *Departments of Neurosurgery, Hospital Kuala Lumpur, 53000 Kuala Lumpur, Malaysia*
2. *Department of Neurosciences, School of Medical Sciences, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia.*
3. *Craniofacial Medical Imaging Cluster Research and Innovation Unit, School of Dental Science, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia*

Corresponding author:

Shukriyah Sulong

Department of Neurosurgery

Hospital Kuala Lumpur

50586 Jalan Pahang Wilayah Persekutuan Kuala Lumpur.

Mobile: +60199718618

Email: shukriyah86@yahoo.com

ABSTRACT

Background: Craniosynostosis is a congenital defect that cause one or more suture to fuse prematurely. Cranial expansion surgery which consist of cranial vault reshaping with or without fronto-orbital advancement (FOA) is done to correct the skull to a more normal shape of the head as well as to increase the intracranial volume. Therefore, it is important to evaluate the changes of intracranial volume (ICV) after the surgery and the effect of surgery both clinically and radiologically.

Objective: This study is to (1) evaluate the ICV in primary craniosynostosis patient after the cranial vault reshaping with or without fronto-orbital advancement and to compare between syndromic and non-syndromic synostosis group, (2) to determine factors that associated with significant changes in the ICV postoperative, and (3) to evaluate the resolution of copper beaten sign and improvement in neurodevelopment after the surgery.

Method: A prospective observational study of all primary craniosynostosis patients who underwent operation cranial vault reshaping with or without FOA in Hospital Kuala Lumpur from January 2017 until Jun 2018. The ICV preoperative and postoperative was measured using the 3D CT imaging and analysed. The demographic data, clinical and radiological findings was identified and analysed.

Result: 14 cases (6 males and 8 females) with 28 3D CT scan were identified. The mean age of patients was 23 months. The patients were 7 syndromic synostosis (4 Crouzon syndrome and 3 Apert syndrome) and 7 were non-syndromic synostosis. The mean preoperative ICV was 880 mL (range, 641-1234 mL) while the mean postoperative ICV was 1081 mL (range,811-1385 mL) The difference was 201 mL which was statistically significant ($P<0.001$). In comparison, the mean volume increment for syndromic synostosis and non-syndromic synostosis were 282 mL and 120 mL respectively. The difference was statistically significant ($P<0.004$). Mc Nemar's test was used to analyse

pre and post-operative changes within the same patients. At 3 months post-surgery, all 13 patients with copper beaten sign pre-operatively did not show complete resolution on 3D CT imaging. Therefore the p-value was insignificant (P>1.0). While 2 patients with neurodevelopmental delay pre-operatively showed no improvement during assessment at 3 months post-surgery. Again the p-value was insignificant (P>1.0). Hence, there were no significant resolution in copper beaten sign and improvement in neurodevelopmental delay in this study.

Conclusion: Surgery in craniosynostosis patients increases the intracranial volume besides it improves the shape of the head. From this study, the syndromic synostosis had better increment of intracranial volume compared to non-syndromic synostosis.

Keywords: *Craniosynostosis, Intracranial volume, 3D CT scan, Cranial vault reshaping, Fronto-orbital advancement*

3.3 INTRODUCTION

Primary craniosynostosis is a congenital malformation due to fusion of one or more sutures during embryogenesis. It occurs in 1 in 2100 to 1 in 2500 births and it can be either non-syndromic or syndromic [1]. Over the first year of life, the brain triples in volume and continue to grow rapidly over the next 2 years and reaching adult size between 6 and 10 years of age. The cranial sutures are essential to growing skull to accommodate the brain growth [3]. The cranial sutures consist of metopic sutures-separate the paired frontal bone, sagittal sutures-separates the paired parietal bone, coronal sutures-separates the paired frontal and parietal bone, and lambdoid sutures-separates parietal and occipital bone [2].

The cranial abnormality will results in abnormal shape of the skull, depending on the sutures that was involved. This insufficient skull growth will result in raised in ICP. Elevation in ICP (defines as 15mmHg or greater during slow-wave sleep) was more common in syndromic cases compared to single suture synsotosis which is reported around 14% [7]. The risk of elevation of ICP depend on the number of affected sutures in the non-syndromic type. Meanwhile, in syndromic patients it is related to multifactorial cause which includes intracranial venous obstruction, hydrocephalus, and upper airway obstruction [9].

The classic presentation of elevated intracranial pressure are headache, nausea, and vomiting. The consequence of delayed in diagnosis of this elevated ICP may cause neurodevelopmental delay in children. Mild impairment in cognitive and motor function have been seen in patient with single suture synostosis. It was reported around 30-35% of school-age children with single suture synostosis have neurocognitive impairment [23]. But in group of syndromic patient, neurodevelopmental delay was worse as it was reported a moderate delay in mental and motor scores [15].

A computed tomography (CT) scanning and three- dimensional reconstruction has become the standard pre-operative diagnostic in craniosynostosis [21]. Typical primary radiological findings including ridging, sclerosis or narrowing of the sutures [28]. Secondary signs are fingerprinting or copper beaten sign, which may indicate raised intracranial pressure [19]. A diffuse copper beaten sign were seen more common in craniosynostosis patient and it is correlate with elevation of ICP. However, it is not recommended as screening tool due to low sensitivity [29].

The surgical correction consist of cranial vault expansion and FOA [22]. Most of surgery was performed between ages of 6 months and 2 years [1]. The aim of surgical treatment are to increase the intracranial volume, thus reducing the risk of developing elevated intracranial pressure and to correct the skull abnormality. However, there is still debate about relationship between intracranial volume and symptoms of raised intracranial pressure and the effect of surgery on intracranial volume.

Therefore, this is a volumetric study using 3D CT scan to measure intracranial volume changes in children with craniosynostosis after the surgery. From this study, we hoping can see the effect of surgery on improvement of copper beaten sign and neurodevelopmental delay.

3.4 METHODOLOGY

3.4.1 Research design

An observational prospective study was conducted on 14 patients who had primary craniosynostosis and underwent operation cranial vault reshaping with or without fronto-orbital advancement in Hospital Kuala Lumpur from January 2017 to Jun 2018. Approval to undertake the study was obtained from the Research and Ethics committee KKM (NMRR 34174). The sample size was calculated based on paired t-test analysis. A sample size of 15 patients required to detect 290 ml changes of intracranial volume preoperative and postoperative at power 80% and 0.05 significant level with 10% dropout.

3.4.2 Study population

The inclusion criteria were all cases in paediatric age group up to 12 years-old, all types of craniosynostosis either non-syndromic or syndromic involving single sutures or more. The surgery was done in Hospital Kuala Lumpur with preoperative CTB 3D was done within 2 months prior to surgery and patients was follow up for at least 3 months or more. The CTB 3D was repeated 3 months after operation and all CTB 3D were readable in DICOM. Meanwhile, the exclusion criteria were patient that had secondary craniosynostosis, patient that underwent re-surgery. Patient that lost to follow up and the CTB 3D without soft copy were also excluded.

3.4.3 Surgical technique

Surgical technique consist of anterior cranial vault reshaping with or without fronto-orbital advancement. For the anterior cranial vault reshaping, we used Pi-technique. Patient was draped in supine position. Anterior scalp was raised through a standard bicoronal incision. A bifrontal craniotomy was performed. Then the bilateral coronal sutures, parasagittal osteotomies and lambdoid sutures were removed. Bilateral

parietal bones were fractured out to increase biparietal diameter. The sagittal suture was used as strut to maintain the outward position of the parietal bones. Finally the frontal and occipital bones were secured to the parietal bones with adjustments of anterior-posterior dimension.

For fronto-orbital advancement, osteotomies on the orbitofrontal bandeau were performed starting on the lateral orbital ridge over the frontozygomatic sutures and opening of the orbital roof. The pterions were resected up to the level of cranial fossa. This bandeau was anteriorly displaced, with lateral extremes of the bandeau projecting forward, maintaining the medial aspect of bandeau in place. Orbital roof and supraorbital ridges were aligned in proper position and then fixed in place with absorbable sutures. The operation ends with a meticulous control of the hemostasis. Subgaleal was closed with absorbable sutures while skin incision is sutured by non-absorbable stitches.

3.4.4 Methods of research

3D CT scan

We retrieved the 3D CT brain data of the studied subject from the database of HKL Radiology department with the permission of the head of unit. All 3D CT brain were conducted in 0.4mm slice thickness. The 3D CT images were transferred in Picture archiving and communication system (PACS) gateway, and organized in Digital Imaging Communications in Medicine (DICOM) format. The selected data that were retrieved from PACS were saved in compact disc (DVD-R).

Volumetric Study

For measurement of ICV in this study, two observer (author and co-author) measured the volume preoperative and postoperative. The first observer measured twice in separates occasion and mean value calculated, and the second observer measured only once. The first observer was new user using the Medical Imaging Interaction Toolkit