THE ASSOCIATION OF FRONTAL SINUS VOLUME WITH TRAUMATIC BRAIN INJURY

BY:

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To my wife : See Hwee Ming,

With her support, encouragement, patience and unwavering love was in the end what made this dissertation possible.

To my son :
Yoshweiin Chong See Wein ,

His cheers and laughter relief my stress.

To my baby daughter:
Nidharshana Chong see Ning

Her Cheekiness and smiles motivate me.

To my late parents:
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Mdm Chong Nyit Ngo

For educating me, financial support me and fulfilled my intellectual development.

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ABSTRAK

Bahasa Melayu

Latar Belakang:

Kecederaan otak merupakan penyebab utama kemasukan dan kematian di hospital bagi penduduk Malaysia. Ia melibatkan generasi muda dan menyebabkan kos yang tinggi dalam segi kewangan dan sumber manusia. Sinus paranasal adalah kawasan berudara yang meliputi sebahagian besar daripada tengkorak dan muka kita. Fungsi sinus paranasal tidak lagi diketahui dengan sepenuhnya. Salah satu teori fungsi sinus paranasal adalah untuk melindungi otak daripada kecederaan dengan menyerap impak. Kami ingin menerokai lebih lanjut lagi teori tersebut.

Objektif:

Untuk mengkaji hubungan antara isipadu sinus frontal dengan perdarahan dalam kalangan pesakit trauma.

Metodologi:

Ini ialah kajian keratan rentas dari Januari 2016 hingga Disember 2016 (12 bulan) ke atas 126 orang pesakit yang menjalani skan otak tanpa kontras di Hospital Universiti Sains Malaysia selepas mengalami kemalangan. Semua skan otak tanpa kontras subjek kajian ini dipaparkan dan dianalisakan melalui aplikasi sistem PACS manakala isipadu sinus frontal diukur dengan mengunakan aplikasi OSIRIX. Data

demografi, jenis kecederaan otak dan ukuran sinus frontal dianalisakan dengan menggunakan aplikasi PASW Statistics.

Keputusan:

Isipadu sinus frontal bagi populasi adalah 9.35 +/- 4.74 cm^3. Jika diambil kira jantina, maka isipadu purata untuk lelaki adalah 8.75 +/- 4.69 cm^3 dan bagi wanita 6.54 +/- 4.61 cm^3.

Terdapat hubungan signifikan antara isipadu sinus frontal dengan kejadian pendarahan dalam otak, keterukan pendarahan otak, jenis pendarahan subdural dan jenis pendarahan subarachnoid.

Kesimpulan:

Sinus frontal yang besar dapat melindungi otak daripada pendarahan dan mengurangkan keterukan pendarahan itu.

ABSTRACT

English

Background:

Brain injury is the major cause of death and hospital admission among Malaysian. It affects primarily younger generation and cost a lot of financial and man power cost. Paranasal sinuses are large area of aerated space anterior to the skull and around the face. There is not complete understanding to the function of the space yet. One of the theories of the function of the paranasal sinuses are as a crumble zone and impact absorber to reduce the injury to the brain . We would like to further explore this theory with this study.

Objective:

To study the association of frontal sinus volume with traumatic brain injury.

Methodology:

This is a cross sectional study from January 2016 till December 2016 (12 months) enrolling 126 patients who presented to the emergency and trauma centre regarding of trauma nature and sustained anterior impact indicated by frontal scalp swelling, facial bone or frontal bone fractures. All the patient underwent CT brain in Hospital Universiti Sains Malaysia. These non-contrast enhanced CT brain images were viewed and analyzed using Picture Archiving Communication System (PACS)

application. The frontal sinus volume were measured with the OSIRIX application. The demographic data, brain injuries and frontal sinus measurements collected were analyzed using PASW Statistics 18 software.

Result:

The mean frontal sinus volume measured 9.35 +/- 4.74 cm^3 disregarding of the gender. Considering gender, the mean frontal sinus volume for male is 8.75+/- 4.69 cm^3, mean frontal sinus volume for female is 6.54 +/- 4.61 cm^3.

There is statistically significant association between the frontal sinus volume with traumatic brain injury, severity of brain injury, subdural bleed and subarachnoid bleed.

Conclusion:

Larger frontal sinus has protective effect on brain in traumatic event and reduce the severity of injury.

CHAPTER 1

INTRODUCTION
&
OBJECTIVES

1.1 INTRODUCTION

Frontal sinus is anatomically located between the inner and outer table of frontal bone. The frontal sinus begin to develop in the intrauterine and continues to grows in chilhood and fully develo at adulhood. The function of the paranasal sinuses are debated for since the discoveries of the sinuses. Review article by Keir,(2009) proposed multiple theories of functions of paranasal sinuses however these theories are not scientifically proven. In recent study by Yu *et al.*,(2014) found that patient with brain contusions tend to have larger frontal sinus volume compare to those without brain contusion. He concluded that frontal sinus protect the brain from injury.

Traumatic brain injury is the event of injury to the brain at the force of external impacts. Most common causes for traumatic brain injury are motor vehicle accident, fall, gun shot and industrial accident. Traumatic brain injury can be divide into subarachnoid bleeds, subdural bleeds, intraparenchymal bleeds and extradural bleeds.

In this study, we would further explore on the theory of frontal sinus act as a protective mechanism onto the brain in the event of trauma. The aim of this study is to evaluate the frontal sinus volume in traumatic brain injury. We will further study the association of the frontal sinus volume in the different types of traumatic brain injury and according to severity of traumatic brain injury. More precise frontal sinus volume measurements were used with 3D volume rendering technique.

Those with larger frontal sinus volume will have lesser occurrence of traumatic brain injury and less severe traumatic brain injury. With this new information, it will provide all new approach on transportation safety and preventive measures in traumatic head injury.

1.2 OBJECTIVES

1.2.1 General Objective

To study the relationship between the volume of the frontal sinus with traumatic brain injury

1. 2.2 Specific Objectives

1. To determine the mean volume of the frontal sinus in patient with and without traumatic brain injury

2. To determine the association between the mean volume of the frontal sinus and severity of traumatic brain injury

3. To determine the mean volume of the frontal sinus and presence among 4 types of intracranial bleed (subarachnoid bleed, subdural bleed, extradural bleed and contusion)

1.2.3 Research Questions

1. Is there low risk for traumatic brain injury for those with larger frontal sinus volume?
2. Is there an association between frontal sinus volume with severity of traumatic injury?

3. Is there higher risk for certain type of bleed if the frontal sinus is smaller in volume?

1.2.4 Hypothesis

1. There is an association between traumatic brain injury with frontal sinus volume.

2. There is an association between frontal sinus volume with severity of traumatic brain injury.

3. There is an association between frontal sinus volume with types of intracranial bleeds.

CHAPTER 2

LITERATURE REVIEW

2.1 Paranasal sinuses , frontal sinus & functions

Frontal sinus are anatomically located between the inner and outer table of frontal bone, posterior to the supercilliary arches and the root of the nasal bone, figure 1.1, 1.2. It begins with evagination of the anterior superior portion of the of the middle meatus which is known as frontal recess. The frontal sinuses grow with pneumotization of the frontal recess. The frontal sinus begin to develop in the fourth fetal months. The growth of the frontal sinus slow in childhood and usually it will be detectable by one year old. The growth of frontal sinus will continue and achieve it maximum size by adulthood , figure 1.3. According to Ezemagu et al , the frontal sinus reach adult size at 15 years old for both male and female gender (Ezemagu *et al*., 2013).

Anatomically, the frontal sinus consist of two chambers. However three or more chambers are possible. The chamber may divided by a thin septa and usually the chambers are unequal in size. 4% unilateral absent of frontal sinus recorded and 5% bilateral absent. Yu et al reported that average frontal sinus volume in patient with contusion of 21.85 cm^3 and patient without contusion with average frontal sinus volume 32.72 cm^3 (Yu *et al*., 2014). Limitation of this study is the reading of the volume are less acurate as the volume is calculated with formula and the volume is relative volume. No study for the definite frontal sinus volume is found.

A review article by Keir (2009) came to conclusion the main consideration of the paranasal sinuses as:

1. imparting resonance of the voice
2. humidifying and warming inspired air
3. increasing the olfactory area
4. providing thermal insulation to the vital parts.
5. absorbing trauma to protect the sensory organs
6. aiding facial growth and architecture
7. evolutionary remnants
8. lightening the skull bone to maintain equipoise of the skull
9. floatation device
10. secret mucus to moisten the nasal cavity
11. aiding nasal cavity immune defense and production of nitric oxide

However the function of the paranasal sinuses are yet to be fully understand and explain scientifically.

There are several studies that concluded that incidence of the facial injury increase the likelyhood intracranial bleed. Keenan et al reported odds ratio of 9.9 in intracranial injury with presence of facial bone fracture among bicyclist (Keenan et al, 1999). Pappachan et al also reported the presence of mid facial fracture increase the likelihood of intracranial bleed, $p = 0.01$ (Pappachan and Alexander, 2006). The higher incidence of intracranial bleed in presence of facial bone fracture likely due to the mode of injury which suggestive of high velocity impact thus increase the chances of both facial bone fracture and intracranial injury.

Yu et al reported that there is significant difference in volumne of frontal sinus among subject with contusion and without contusion. He reported p = 0.023 (Yu *et al.*, 2014).

A study on cadaveric male skull sample done by Cormier et al in 2009. Cormier had directed blunt force of various forces onto the cadaveric skull at the frontal bone region and found that cadaveric skull with frontal sinus tend to fracture at lower blunt force. Fracture risk of frontal bone with frontal sinus at 1600N and without sinus at 2500N. No nature of bleed was assessed in his study (Cormier *et al.*, 2011)..

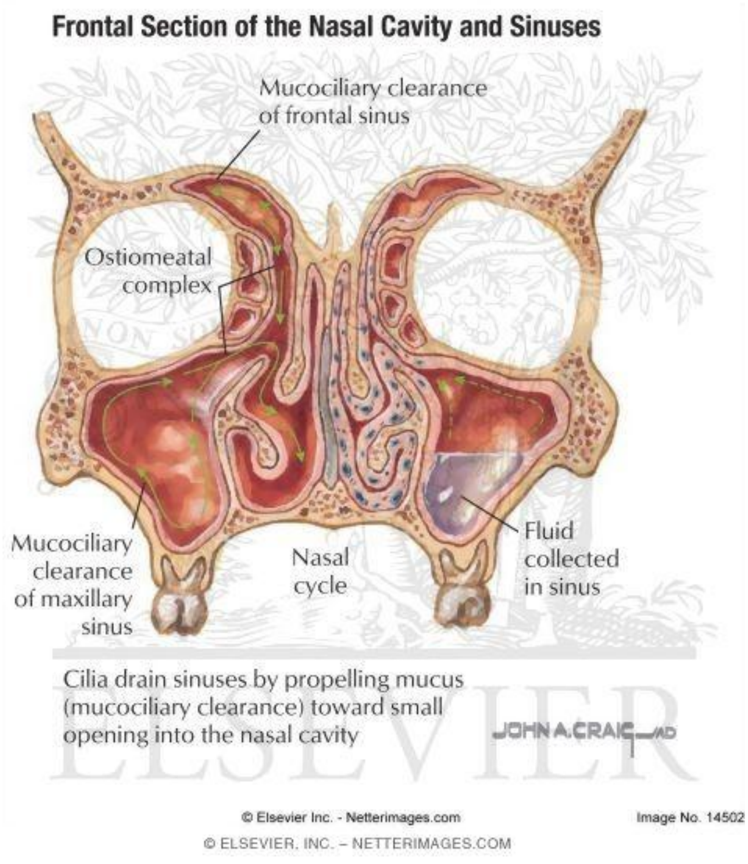

Figure 1.1 Frontal sinus and its drainage in coronal view.

Source from www. netterimages.com

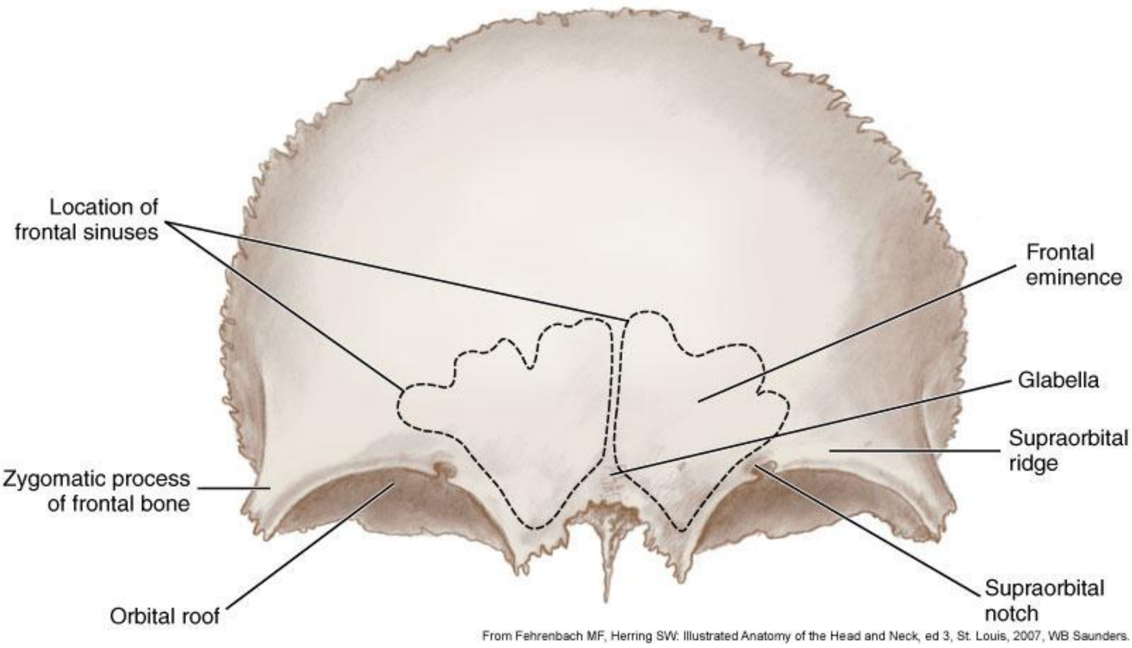

Figure 1.2 Frontal bone and location of frontal sinus.

Source from i3dlearning.pbworks.com

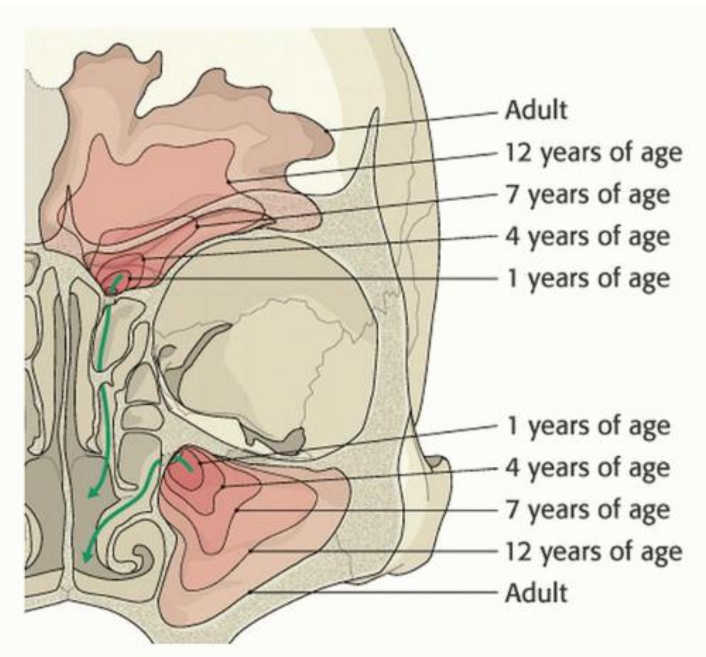

Figure 1.3 : Development of the frontal sinus.

Source from www.aofoundation.org

2.2 Traumatic brain injury

Traumatic brain injury is insult to the brain from an external mechanical force, possibly leading to permanent or temporary impairment of cognitive, physical, and psychosocial functions, with an associated diminished or altered state of consciousness.

According to National Trauma Database, the forth report (Jan, 2009- Dec, 2009) with trauma data collected from 8 participating centres in Malaysia for the period, 76.8% of the trauma at that period are due to motor vehicles accidents (MVA) with motorcyclist at higher risk of MVA - 66.0% of all MVA. Injuries from home accounted for 6.8% of total cases while 5.0% of the injuries at industrial/construction areas. 85.36% of the case had head and neck injury and 65.68% of the patient had underwent CT brain. Only 71.6% the MVA patient survived the injury disregarding of the injuries. Average length of stay in hospital was recorded as 11days (Faizah *et al*., 2009).

Based on JKR Road Safety Statistic Report 2016 edition (Jabatan Keselamatan Jalan Raya, 2016), there are total of 27.6 million registered vehicle with registered road user 15.2 million people. Out of registered vehicles, 12.7 millions are motorbikes (45.9%) and 13 millions are cars (47.1%). A total 7152 people died in that period due to MVA, out of this number 4485 are motorbike riders/pillion riders and 1,489 are car drivers/passengers. According the report from 2007 to 2016, in 9 years period, a total of 67667 people had died due to MVA, out of it 41,155 (60.8%) are motorbike riders/pillion riders. Kelantan had total number of 10544 MVA in 2016 resulting in 453 deaths.

Among ASEAN countries , Malaysia ranked 4th in term of death due to MVA with total of 6915 deaths behind Indonesia, Thailand and Vietnam. Malaysia ranked third in term of deaths/100000 population. Malaysia recorded 24 deaths/100000 population, behind Thailand 36.2 and Vietnam 24.5.

According to National Trauma Database, the forth report (Jan 2009-Dec 2009), around 3489 cases (78.35%) of all the cases with Abbreviated Injury Score (AIS) ≥ 3 are with head and neck injuries. A total of 1354 cases underwent CT brain and a total of 673 patient underwent cranial surgery (National Trauma database 4th report, 2011).

Traumatic head injury can be classified as mild, moderate and severe. Definition from the head injury interdisciplinary special interest group of the American Congress of Rehabilitation Medicine :

1. Mild traumatic head injury :

   Disruption of physiological disruption of brain function manifest with Loss of conscious, loss of memory, alteration of mental status and transient/permanent focal neurological deficit.

   GCS score >12

   Hospital stay <48 hours

   Normal CT findings.

2. Moderate traumatic head injury:

   GSC score 9-12

   Hospital stay < 48 hours

   Operative intracranial lesion

   Abnormal CT findings

3. Severe traumatic head injury:

   GSC score 3-8

   Hospital stay > 48 hours

There are various types of traumatic intracranial injury . The brain may suffer from primary insults such as extradural bleed, subdural bleed, brain contusions/ intraparenchymal bleed, subarachnoid bleed, diffused axonal injury or secondary insults such as brain edema and herniation.

From the study by Kumar et al (2008), autopsy from the post MVA patients, Kumar found that types of intracranial bleed in these patient as subdural 1514 (89.11%) , subarachnoid 1240 (72.98 %), intraparenchymal bleed 282 (16.60%) and extradural bleed 344 (20.25%).

Subdural and subarachnoid bleed are the commonest intracranial bleed. However it is proven that extradural bleed is the bleed that is most beneficial with surgical treatment and with better outcome. Extradural bleed is associated with skull fracture. The mortality rate carries 5-15%.

However surgical intervention and treatment is needed in other type of bleed once there is significant indirect signs of brain injury, which indicate presence of mass effect and herniation. The most common indicator of this is midline shift and effacement of basal cistern.

Radiological assessment is therefore crucial in treating and managing all the patients with traumatic brain injury in acute and during the stay in hospital.

CHAPTER 3

METHODOLOGY

3.0 METHODOLOGY

3.1 Study Design

This was a cross sectional study performed in Hospital Universiti Sains Malaysia (HUSM) from January till December 2016 over a span of 12 months. One hundred and twenty six trauma patients in whom CT brain were indicated became the subject of the study. Ethical approval was obtained from The Human Research Ethics Committee of USM (JEPeM).

3.2 Inclusion and Exclusion criteria:

Inclusion criteria:

1. Patients who sustained any form of trauma
2. Patient who were indicated for CT brain
3. Patients who had signs of frontal trauma include:
    a. Frontal scalp swelling
    b. Frontal bone fracture
    c. Facial bones fracture

Exclusion criteria:

1. Patients who had previous frontal craniectomy or any other surgery involving the frontal sinus

2. Patients who were from pediatric age group (<15years old)

3. Patients who having bony tumour involving the frontal bone

3.3 SAMPLE SIZE

3.3.1 Source population:

Patients who had head injury and underwent CT brain in Hospital Universiti

Sains Malaysia.

3.3.2 Sampling frame:

Those who fulfill inclusion criteria would be assessed for

1. the presence of any type bleed.
2. the severity of head injury using Marshal score.
3. measures volume of frontal sinus using OSIRIX program.

3.3.3 Sampling method :

Convenience sample method was used where all the patient who had underwent CT scan for brian injury where included until the number of sample are achehieved

3.3.4 Sample size calculation:

Sample size was calculated by Power and Sample Size Program 3.0.10.

General objective

The average frontal sinus volume measures 3.90 ±0.44 cm^3 (1 SD) (Nataghian et al, 2016). The difference of frontal sinus volume in traumatic contusion with no contusion as 33%. With power 0.9, σ 0.33, α 0.05, δ 0.44

The calculated sample size for each group as 38. Total of 76 samples for both groups.

3.4 Research Tools

1. Siemens SOMATOM Definition AS 128-Slice Multi detector CT scan

   Reconstructed images of both brain and bone windows would be utilized.

2. Picture Archiving Communication System(PACS) PACSIW software

   version 3.7.3.using BARCO Image display system.

3. Osirix 8.0 program with MAC IOS system.

3.5 CT Brain Imaging Protocol

These studies were done with patient placed in supine position. For co-operative adult patients who were able to obey command, CT scan was performed as close to the standard CT brain protocols possible. However, for patients who were unable to follow command, suspected of sustained cervical injuries, difficult intubation, scanning protocol was modified accordingly because of the potential of further accentuated cord injury and endotracheal tube dislodgement that cannot be compromised.

Standard CT brain trauma protocol for adult patient in HUSM is as followed:

Setup:

1. Supine, AP and lateral scouts.
2. Scan start at the bottom of C2 and scan through till the top of the head.

Table 1: Trauma Protocol For Head (Adult) in HUSM

Trauma Protocol For Head (Adult)	
Scanner	Siemens Somatom Definition Adaptive Scanner(AS) 128 slice
Scan type	Helical
Detector rows	64
Slice thickness	5mm
Rotation time	1.0sec
kV/mA	120/410
FOV	Head
Recon1	
Recon type	Soft tissue
Kernel	H31 soft medium Smooth
WW/WL	80/35
Recon2	
Recon type	Bone
Kernel	H70 hard very sharp
WW/WL	1500/450

3.6 Image Interpretation

Evaluation of the images and measurement were done by the researcher. Evaluation of the images was done in 2 stages. In the first stage, non-contrast enhance CT brain in brain parenchymal window is assessed for the type of bleed and severity of the bleed using Picture Archiving Communication System (PACS) PACSIW software version 3.7.3. on designated workstation. Severity of the head injury is assessed with Marshal Score.

Marshal score:

1: no mid line shift, basal cisterns are not effaced. No visible brain pathology.

2: < 5mm midline shift, basal cisterns are not effaced.

3: > 5mm midline shift, basal cisterns are not effaced.

4: > 5mm midline shift, basal cisterns are effaced.

All values were documented on the patient's datasheet (Appendix 1). At the second stage, non-contrast enhance CT brain in bone window is asses using OSIRIX 8.0 program to assess the frontal sinus volume. Both first stage and second stage is done blinded to avoid bias in interpretation or volume measurements.

3.7 Frontal Sinus Volume Measurements

Frontal sinus volume is measures using OSIRIX 8.0 program. Using the bone window, frontal sinus anatomy is identified (Figure 5). The frontal sinus is evaluated in 3 planes. Presence of fractures is identified. With the function of ROI in OSIRIX, the outline of the frontal sinus is draw carefully at axial plane with guidance of sagittal and coronal view (Figures 6 & 7). Minimum of 10 outline of the frontal sinus is drawn. This is follows by generating missing ROI of the frontal sinus in the other cuts (Figures 8 - 11). The generated ROI is further check and readjust to obtain most satisfy outline of the frontal sinus. With most satisfied outline of ROI, frontal sinus volume is generated (Figures 12 & 13). The produced frontal sinus volume image is saved and recorded (Figures 14).

Figure 4: CT brain at bone windows at the level of frontal sinus

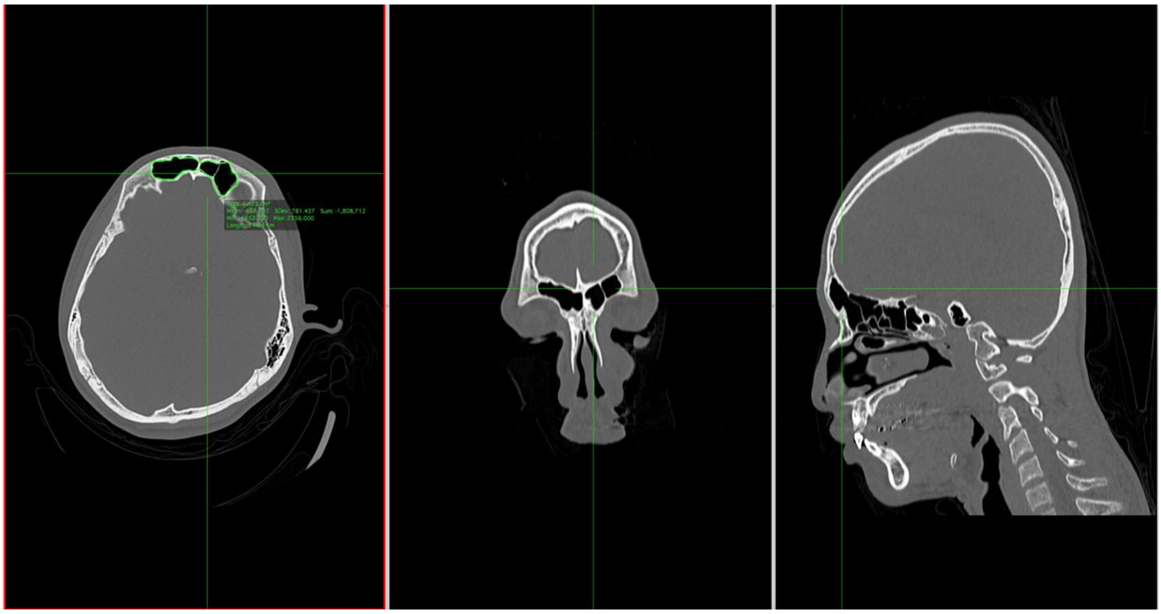

Figure 5: Outline of the frontal sinus is identified with guidance of sagittal and coronal view.

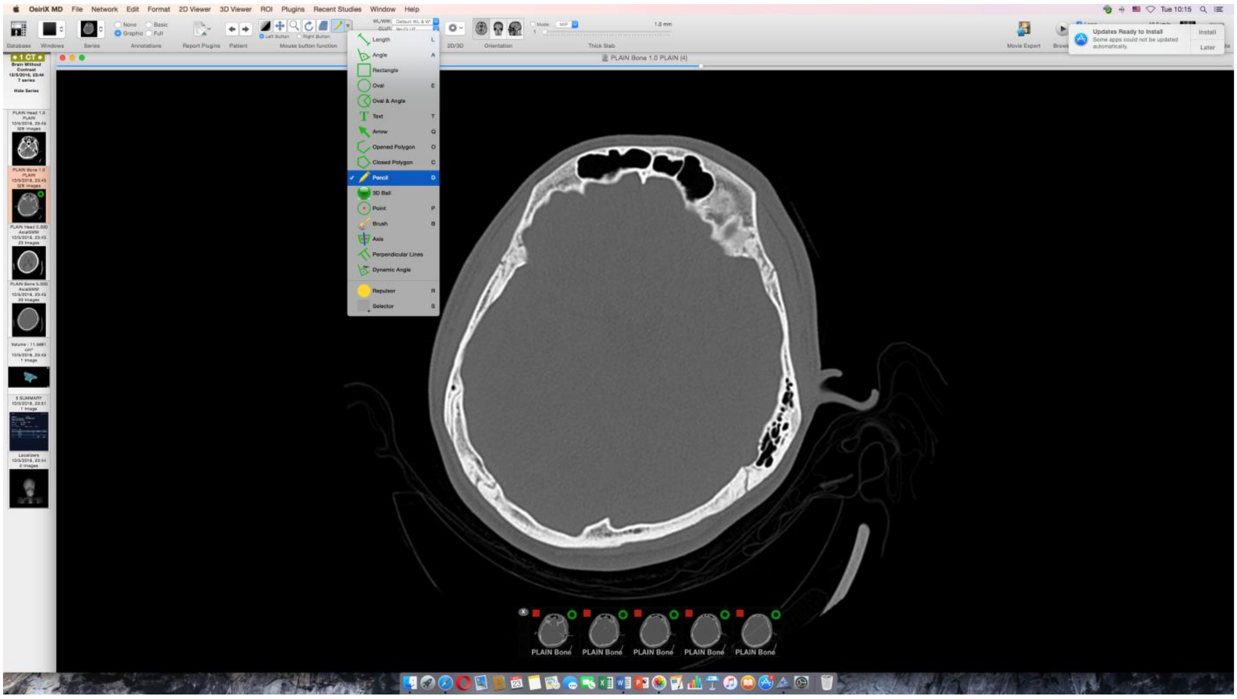

Figure 6: Pencil icon in Osirix to draw the outline of the frontal sinus

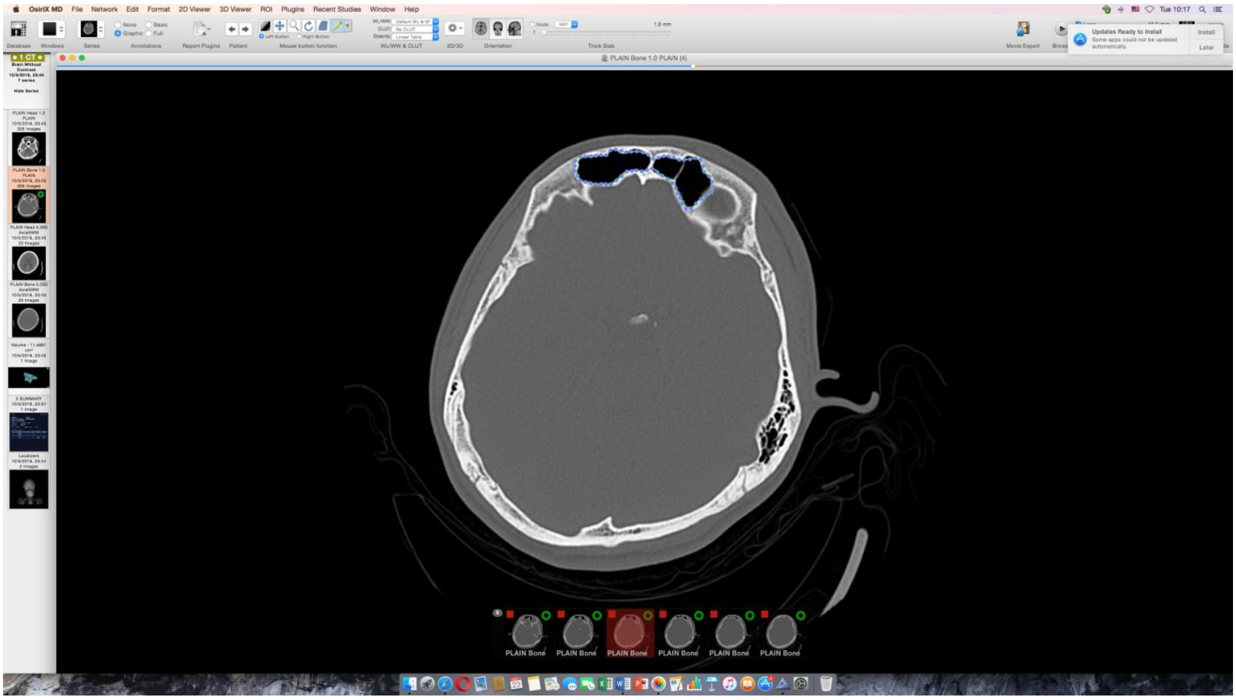

Figure 7: Frontal sinus outline drawn.

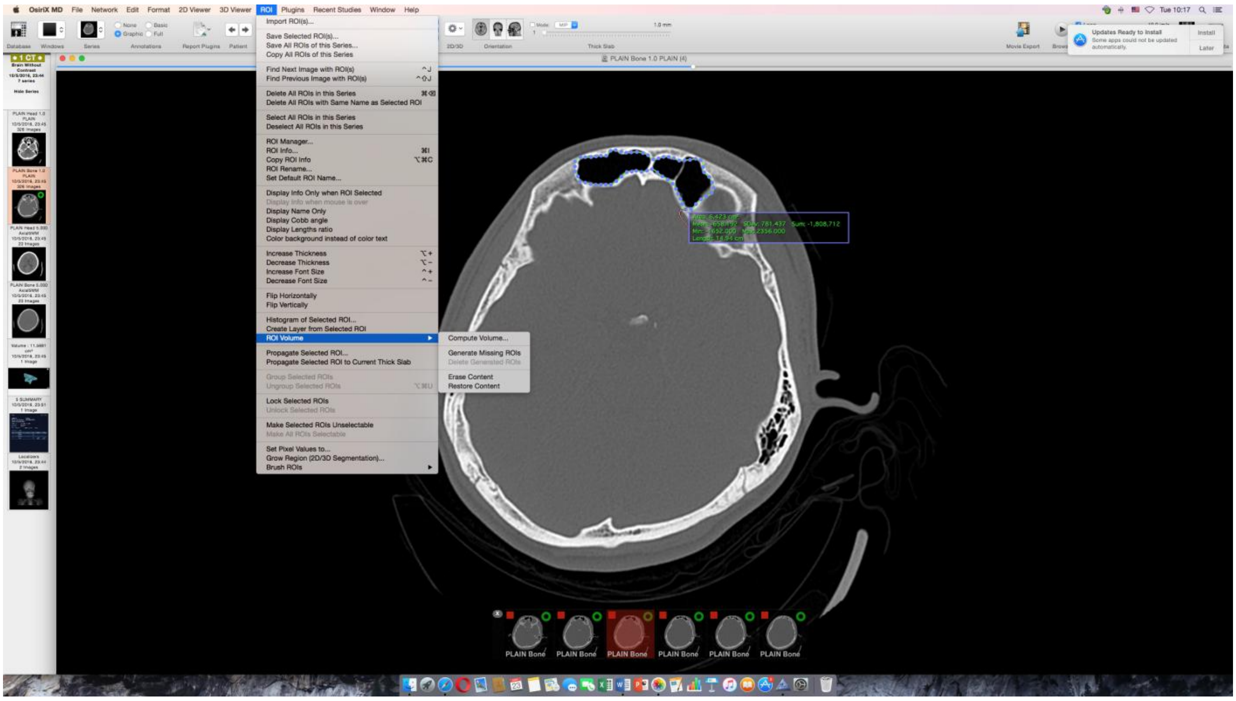

Figure 8: The ROI volume button.

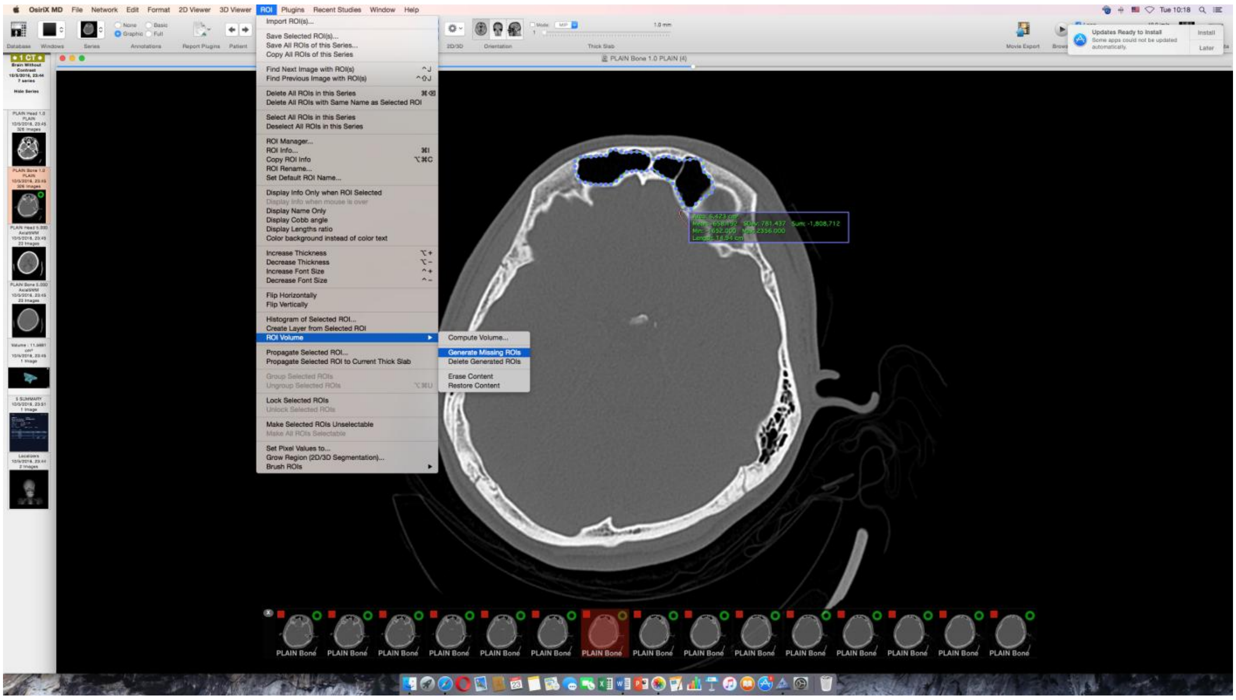

Figure 9: As least 10 outline of the frontal sinus is drawn in axial view. The rest of the ROI is generated with missing ROI button as shown.

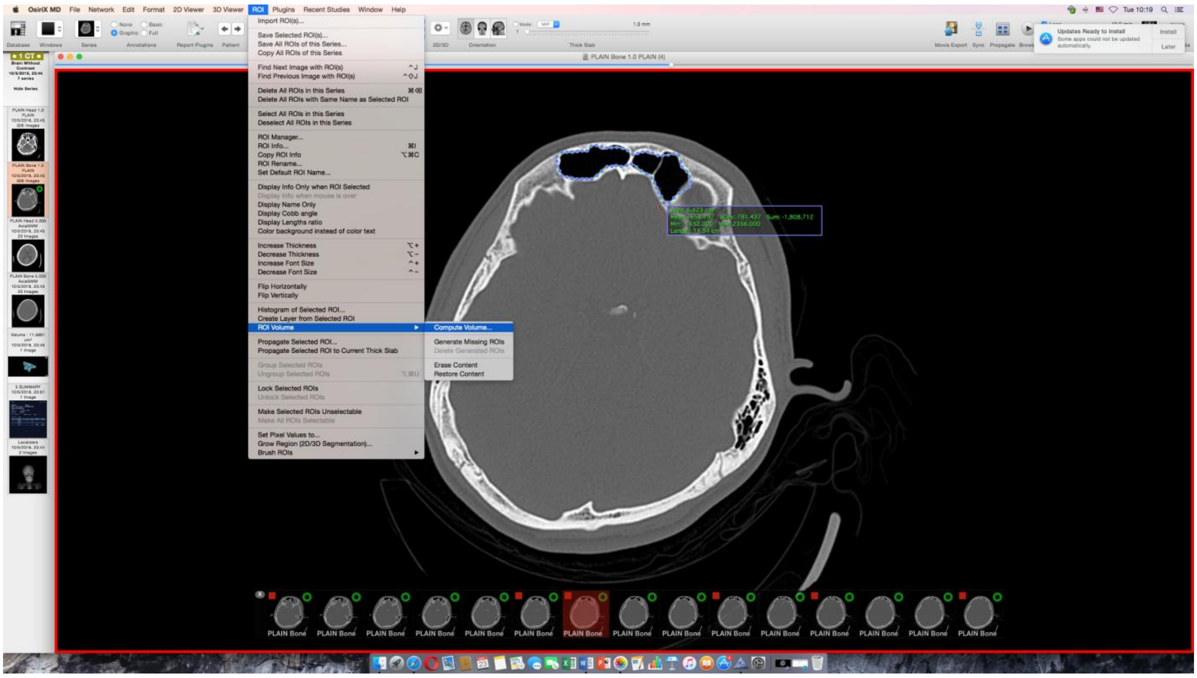

Figure 10: The generated ROI is checked and modified to resemble the outline as near as possible. Once the ROI outline is satisfied, compute volume is clicked as shown in the figure.