Oregon Health & Science University
School of Medicine

Scholarly Projects Final Report

Title: Traumatic hematoma volumes measurements with 3D-Slicer software may show less variation when compared to ABC/2 formula

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Scholarly Project Final Report

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Project/Research Question:
In a retrospective analysis of CT scan images from a group of prospectively enrolled patients with progression of traumatic cerebral hematoma, is there a difference in volumes measured between the conventional ABC/2 formula and a semi-automated computer software, 3D-Slicer.

Type of Project: Research study

Key words: traumatic brain injury, cerebral hematoma, volumetrics, progression of cerebral hematoma

Meeting Presentations: None

Publications: None

Submission to Archive: No restrictions.

Next Steps: Investigate influence of overall hematoma volume on the accuracy of measurement method, correlate clinical outcomes with hematoma volumes, validate 3D-Slicer measurement consistency between readers, repeat study with larger sample size.

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This report describes work that I conducted in the Scholarly Projects Curriculum or alternative academic program at the OHSU School of Medicine. By typing my signature below, I attest to its authenticity and originality and agree to submit it to the Archive.

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March 10, 2023

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Scholarly Project Final Report

Report*:*

Introduction

Traumatic brain injury (TBI) is a common and increasing cause of morbidity and mortality in the United States. It is currently suggested that 2% of the US population currently lives with disabilities that resulted from a TBI[1]. Additionally, TBI is a large component of emergency department (ED) visits and hospitalizations leading to increased health care costs. A recent surveillance report from the CDC found that during 2014, in the US, there were about 2.5 million TBI-related emergency department visits, 288,000 TBI-related hospitalizations, and 56,800 TBI-related deaths.[2] Overall the cost estimates of TBI are varied, but have been between $56 to $221 billion annually.[3]

The pathology and features of TBI are heterogeneous in nature. Primary brain injury is sustained at the time of the trauma; however, secondary brain injury can continue for hours, days and months after this initial trauma. This is often a progression or exacerbation of the primary brain injury. Cerebral hematomas can be seen on non-contrast computed tomography (CT) in 13%-35% of patients following a TBI[4]. One of the significant forms of secondary brain injury seen after TBI is progression of those hematomas, which often correlates with subsequent clinical deterioration and requirement of a neurosurgical intervention such as intracranial pressure monitoring and/or a craniotomy[1]. As result, many studies have sought to better understand both clinical and radiological parameters for this progression. Many factors have been associated with hemorrhagic progression[5], but initial contusion volume has been positively associated with progression[6]. Initial volume of the contusion has been found to be the most predictive factor of progression and significantly associated with a worse 6-month outcomes[4,7].

Having a method to measure hematoma volume quickly and accurately on CT scans is an important factor in improving outcomes associated with TBI. The ABC/2 method is widely used as a bedside measure of hematoma volume in spontaneous intracerebral hemorrhage and assumes an idealized ellipsoid shape[8]. There is increased interest in using semi-automated methods to measure hematoma volumes. In this study, we aimed to compare the ABC/2 formula with the software 3D Slicer in a sample of traumatic cerebral hematomas.

Methods

Subject selection:

Retrospective observational study using imaging data from a subset of patients from a cohort of prospectively enrolled patients with injuries serious to warrant an ICU stay both with and without TBI from a level 1 trauma center between October 2013 through June 2015. Subjects with TBI were the further divided into those who had intracranial hemorrhage on head computed tomography (CT) upon admission. For those with intracranial hemorrhage, hematoma progression was defined as 30% or greater hematoma volume increase, worsened traumatic subarachnoid hemorrhage, presence of new hemorrhagic lesion on the second head CT.

All patients in the initial cohort who met the definition for major trauma were approached for consent. Any patient who refused to consent, could not be consented or who were not admitted to the ICU were excluded. In those patients who were deemed unable to consent for themselves, consent was obtained from the patient's legally authorized representative and then were re-consented if they regained ability to

provide consent during hospitalization[9].

Imaging and volume measurement:

In the 3D Slicer group, de-identified image data sets in Digital Imaging and Communications in Medicine format were downloaded to a standard personal computer to load into the software. Hematoma volumes were measured by one individual on axial head CTs using the freely available semi-automated image processing tool, 3D Slicer[10]. Hematoma was automatically identified in each slice after setting the threshold range at 50 to 100 HU. After initial pixel identification, each slice was re-visited to manually erase erroneous segments or touch up selected area. 3D Slicer then constructs a three-dimensional model, and a total volume is calculated by given by accumulating the volume of all identified (Figure 1).

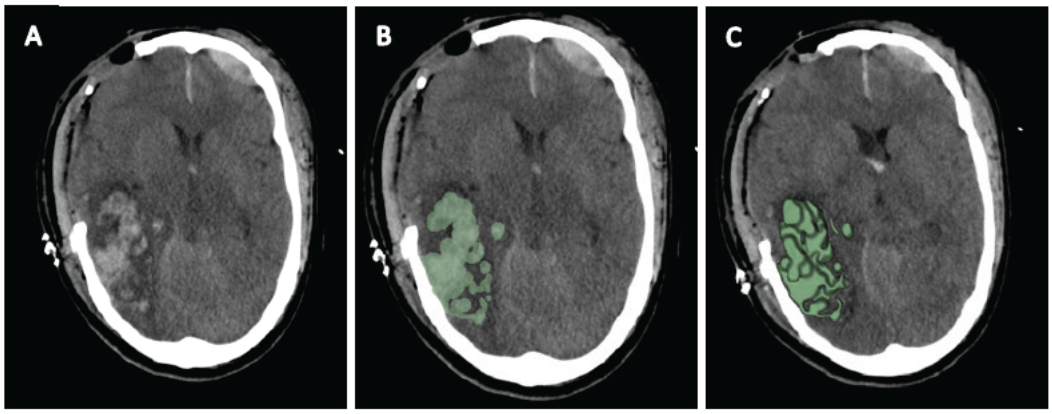

Figure 1. CT scan of hematoma (A) shown with corresponding tracing (B) and 3D-Slicer reconstruction (C)

In the ABC/2 group, the measurements were taken on the viewer of the Picture Archiving and Communication System by two individual reviewers. Briefly, this previously described method uses the formula ABC/2, where A represents the greatest hemorrhage diameter by CT, B is the diameter measured 90° to A, and C is the approximate number of CT images slices which show hemorrhage multiplied by the slice thickness[8]. Each group was blinded of the other groups volume measurements until the time of data analysis.

Statistical analysis:

All statistical analyses were performed using the program R[11]. Paired *t*-test was used for comparison of the mean volume of ABC/2 group one versus ABC/2 group two, ABC/2 group 1 versus 3D-Slicer group and ABC/2 group two versus 3D-slicer group. Pearson's correlation was used to correlate measurements between ABC/2 group 1 and ABC/2 group 2. A value of $p \leq 0.05$ was considered statistically significant.

Results

Study population

A total of 13 patients were included in the final analysis. Of these, ten (76.9%) were cis male, three (23.1%) were cis female, and zero were non-binary, transman, or transwoman patients. The mean age upon admission was 42 years +/- 17. Nine (69.2%) of the patients were white, four (30.8%) declined to answer, and zero of the cohort identified as Asian, Black or African American, Pacific Islander or Native Hawaiian, Native American or Native Alaskan, Middle Eastern and North African, or other. One (7.7%) patient identified as Hispanic or Latinx, eight (61.5%) identified as non-Hispanic or non-Latinx and four (30.8%) declined to answer.

The mean admission GCS score was 6 +/- 3. The mean time from initial head CT was 6 hours and 52 minutes +/- 4 hours 27 minutes, with a range between 2 hours and 51 minutes and 20 hours and one minute.

Table 1. Characteristics of the Study Population

	Overall (N=13)
Gender:	
Cis Male	10 (76.9%)
Cis Female	3 (23.1%)
Non-binary	0 (0%)
Transman	0 (0%)
Transwoman	0 (0%)
Age upon admission:	
Mean (SD)	42 (± 17)
Admission GCS Score:	
3	5 (38.5%)
4	2 (15.4%)
5	0 (0%)
6	0 (0%)
7	1 (7.7%)
8	1 (7.7%)
9	1 (7.7%)
10	2 (15.4%)
11	0 (0%)
12	1 (7.7%)
13	0 (0%)
14	0 (0%)
15	0 (0%)
Race	
White	9 (69.2%)
Black or African American	0 (0%)
Asian	0 (0%)
Pacific Islander or Native Hawaiian	0 (0%)
Native American or Native Alaskan	0 (0%)
Middle Eastern and North African (MENA)	0 (0%)
Other	0 (0%)
Decline to answer	4 (30.8%)
Ethnicity	
Hispanic or Latinx	1 (7.7%)
Non-hispanic, non-Latinx	8 (61.5%)
Decline to answer	4 (30.8%)

ABC/2 investigator one vs. ABC/2 investigator two

Hematoma volume measurements were significantly correlated between the two investigators that employed the ABC/2 formula; however, the confidence interval was wide (coefficient = 0.66 (95% CI: 0.370-0.835, p <0.001). The mean difference in volume measurements was significant (8.94 mL, $p < 0.001$).

ABC/2 overall vs. 3D-Slicer

In the 3D-Slicer group, the mean initial hematoma volume measured was 15.6 mL +/- 15.3, with a range from 0 mL to 49.6 mL. The mean hematoma volume measurement at the second CT was 21.8 mL +/- 17.7, with a range from 0 mL to 62.5 mL. The mean difference in hematoma volume between 3D-Slicer and ABC/2 investigator one was significant (10.6 mL, $p = 0.002$). However, the mean difference in hematoma volume between 3D-Slicer and ABC/2 investigator two was not significant (1.75 mL, $p = 0.57$).

Discussion

In this study, we retrospectively used CT images from a group of prospectively enrolled patients with progression of a traumatic cerebral hematoma to quantify differences in volumes measured between the conventional ABC/2 formula and a semi-automated computer software, 3D Slicer. While the use of ABC/2 in measuring volume in spontaneous intracerebral hemorrhage has been validated across studies[8], its use in traumatic cerebral hematomas has not, yet it remains the most commonly used method to measure the volume traumatic brain hematomas on imaging. We hypothesized that the two methods would produce similar results in our cohort.

An important aspect of any methodology that will be employed by many different individuals is inter-reader reliability. In our analysis of two independent ABC/2 measurers, we found that while the ABC/2 measurements were positively correlated, the 95% confidence interval was wide and the difference in

mean hematoma volumes between the two observers was significant. Our results suggest measuring hematoma volumes by the ABC/2 method may display more variability between users in traumatic hematomas. These findings are inconsistent with previous literature which found no difference in the volume measurements of traumatic intracerebral hematoma using the ABC/2 formula between two independent readers[12]. Given the importance of an accurate volume measurement in the clinical setting and the reality of multiple providers employing the volumetric method, an ideal method would not have as much inter-user variability. In terms of the 3D-Slicer group, we are unable to draw conclusions relating variability between users with the 3D-Slicer method because only one individual employed it. Additionally, current literature comparing computer assisted volumetrics to ABC/2 formula in both spontaneous and traumatic cerebral hematomas did not comment on the agreement of computer assisted volumetric measurements between users[7,13]. Future studies should seek to determine the consistency of 3D-Slicer between users.

There is growing evidence that the ABC/2 method has increased variability in measurements based on hematoma shape and overall volume, even in spontaneous cerebral hematomas[13]. While we did not directly analyze the morphology or shape of the hematomas in this study, qualitatively, there were a large variety of hematoma morphologies. Additionally, we noticed that in general, when hematoma volumes were large, the volume measurements were more variable in all methods. The direction of the variability in our study was not consistent. A recent large study compared volume measurements from ABC/2 with 3D-Slicer in traumatic cerebral hematomas but subcategorized them based on hematoma morphology. For solitary intraparenchymal hematomas, they found a trend towards the mean 3D-Slicer volume measurements being larger than the ABC/2 volume measurements, but this finding was not statistically significant or associated with the size of the lesion. However, they found a significant difference in mean volume measurements when comparing the two methods in a subset of multifocal traumatic contusions[7], similar to part of our findings that suggests a significant difference in mean volumes between 3D-Slicer and ABC/2.

In addition, this difference was associated with lesion size. In smaller bleeds, the ABC/2 method underestimated volumes compared to the 3D-Slicer method, but as bleed size increased the relationship flipped and the ABC/2 method overestimated volumes compared to the 3D-Slicer method[7]. This suggests that the measurement of traumatic cerebral hematomas is highly variable, some of which might not have been captured in our analysis of the data. This variability might explain some of the differences seen when comparing volumes between techniques and users in our study. As hematoma volumes become larger, certain measurement methods might be more consistent (or less consistent) which could explain how the mean change in hematoma volume could differ between the two methods.

A limitation of our study is the small sample size; however, our results suggest that there is variation between methods and a larger cohort could further delineate the differences in volume measurements and their relationship with certain clinical outcomes. While conclusions regarding inter-reader reliability of the ABC/2 method, only one observer carried out the 3D-Slicer method. Future studies could look at the accuracy of using that method between individuals.

Conclusions

In conclusion, our findings demonstrate that there are statistically and clinically significant differences in mean hematoma volume when comparing ABC/2 to 3D-Slicer; however, there was a large degree of variability in the measurements potentially related to volume of hematoma. This suggests that 3D-Slicer measurements might be more consistent at larger hematoma volumes when compared to ABC/2 measurements.

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