Membrane Surface Area to Volume Ratio in Chronic Subdural Hematomas: Critical Size and Potential Postoperative Target

Appukutty Manickam[1], Laurence A.G. Marshman[1,2], Ross Johnston[3]

■ BACKGROUND: **It is unknown why some chronic subdural hematomas (CSDHs) grow and require surgery, whereas others spontaneously resolve. Although a relatively small CSDH volume (V) reduction may induce resolution, V percent reduction is often unreliable in predicting resolution. Although CSDHs evolve distinctive inner neomembranes and outer neomembranes (OMs), the OM likely dominates the dynamic growth-resorption equilibrium. If other factors remain constant, one previous hypothesis is that resorption could fail as the surface area (SA) to V ratio decreases when CSDHs exceed a critical size. We aimed to identify a critical size and an ideal target, which implies resolution without recurrence.**

■ METHODS: **Three-dimensional computed tomography CSDH SA to V ratios were obtained using computer software to compare CSDH SA to V between cases requiring surgery (surgical) and cases managed conservatively with spontaneous resolution (nonsurgical).**

■ RESULTS: **Data were obtained in 45 patients (surgical: n = 28; nonsurgical: n = 17). CSDH risk factors did not significantly differ between surgical and nonsurgical cases. Surgical V was 2.5× the nonsurgical V (119.9 ± 33.1 mL vs. 48.4 ± 27.4 mL, respectively; *P* < 0.0001). Surgical total SA was 1.4× nonsurgical SA (256.63 ± 70.65 cm^2 vs. 187.67 ± 77.72 cm^2, respectively; *P* = 0.004). Surgical total SA to V ratio was approximately one half that of nonsurgical SA to V ratio (2.14 ± 0.90 mL^{-1} vs. 3.88±1.22 mL^{-1}, respectively; *P* < 0.0001). Surgical OM SA (SA_{OM}) was 120.63 ± 52 cm^2, and nonsurgical SA_{OM} was 94.10 ± 41 cm^2 (*P* < 0.0001). Nonsurgical SA_{OM} to V ratio was 1.94 mL^{-1}, whereas surgical SA_{OM} to V ratio was 1.005 mL^{-1} (i.e., surgical $SA_{OM} \approx V$).**

■ CONCLUSIONS: **Because surgical total SA to V ratio was ≈2:1, one neomembrane may indeed dominate the dynamic growth-resorption equilibrium. CSDH critical size therefore appears to be when $SA_{OM} \approx V$, which is intuitive. Practically, subtotal CSDH evacuation which approximately doubles total SA to V ratio or SA_{OM} to V ratio implies CSDH resolution without recurrence. This could guide subdural drain removal timing, discharge, or transfer. Prospective validation studies are required.**

INTRODUCTION

It is unknown why some chronic subdural hematomas (CSDHs) inexorably grow and require surgery, whereas others remain static, or even spontaneously resolve. Ultimately, CSDHs may only be resorbed across their membrane surfaces. Histologic analyses have established that CSDHs evolve distinctive inner neomembranes (IMs) and outer neomembranes (OMs).[1-6] However, it is most likely that the OM dominates the dynamic equilibrium between CSDH growth and resorption.[1-6] If other factors remain constant, Apfelbaum et al.[3] hypothesized that CSDH resorptive capacity could conceivably fail purely as the physical ratio of effective CSDH surface area (SA) to volume

Key words
- Membrane
- Subdural hematoma
- Surface area
- Volume

Abbreviations and Acronyms
CSDH: Chronic subdural hematoma
CT: Computed tomography
DBL: Dural border layer
IM: Inner neomembrane
OM: Outer neomembrane
SA: Surface area
SA_{OM}: Surface area outer neomembrane
V: Volume

From the [1]Department of Neurosurgery, The Townsville Hospital, Douglas, Townsville; and [2]School of Medicine and [3]Department of Marine & Tropical Biology, James Cook University, Douglas, Townsville, Queensland, Australia

To whom correspondence should be addressed: Laurence A. G. Marshman, M.D. [E-mail: l.a.g.marshman@btinternet.com]

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(V) necessarily decreases with progressive CSDH growth. Apfelbaumet al.[3] hypothesized a critical size in determining CSDH development; however, the existent experimental technology could not provide this.

As evidenced on postoperative computed tomography (CT) scan, CSDH evacuation (by whatever surgical means) is rarely complete: a residual CSDH typically remains. Therefore, even by day 10, Markwalder et al.[7] found that 78% of operated CSDH demonstrated residuals on CT scan. Despite this, and perhaps surprisingly, most CSDH residuals eventually spontaneously resolve, without any further intervention. Indeed, evacuation of even 20% of CSDH V may suffice to induce spontaneous CSDH resolution.[8] However, early postoperative V percent reduction is often unreliable in predicting clinical resolution. More typically, continued subdural drainage over a variable postoperative period is required: the drainage period, however, is ill-defined.[9] Ultimately, between 9% and 24% of postoperative CSDH residuals (dependent on drain usage) constitute symptomatic short-term recurrences. Although recurrences do not affect long-term survival,[10] recurrences necessitate reoperation and prolong in-hospital stay.[9] Despite considerable efforts, it remains unknown which factors influence recurrence from CSDH residuals. The critical CSDH size of Apfelbaum et al.[3] regarding a surgical target therefore remains elusive.

We set out to compare the SA to V ratio between CSDH cases requiring surgery (surgical) and those managed conservatively with spontaneous resolution (nonsurgical) to potentially identify distinguishing threshold values and a critical size.[3] Such values could potentially identify ideal postoperative CT scan surgical targets, which might imply subsequent resolution without recurrence. If met, such ideal targets could guide subdural drain removal timing, and even discharge or transfer.

MATERIAL AND METHODS

Adult patients with symptoms and signs requiring neurosurgical admission between 2006 and 2011 were initially retrospectively screened (N = 155). Children less than 18 years of age were excluded because chronic subdural collections in this age group potentially represent a distinct pathologic entity.[11]

Patients were ultimately included where CT scans were available for computer software analysis. Patients were specifically excluded where CT scans had demonstrated significant isodense, tentorial, and interhemispheric CSDHs, or where clinical data were lacking. Patients administered corticosteroids were also excluded because primarily physical factors were intended for study. The principal target group for this preliminary study was those with CT scans which demonstrated a convexity CSDH of suitable density, such that the CSDH sufficiently contrasted with the brain to permit accurate and precise estimation. Recurrences were defined as symptoms attributable to a recollection requiring reoperation during convalescence, and within 6 months of surgery.

One observer (A. Manickam) performed all radiologic measurements (intraclass correlation coefficient, 0.87; 95% confidence interval, 0.85–0.94) from individual patient CT brain scans. Surgical measurements used for analysis were performed on CT scans immediately prior to surgery. CT scans in nonsurgical patients were repeated weekly until spontaneous resolution: nonsurgical measurements used for analysis related to the CT scan demonstrating the maximal CSDH V in each patient. OsiriX (Pixmeo SARL, Bernex, Switzerland) software was used on CT scans obtained from a Philips 64-slice MX8000 CT scanner, Amsterdam, The Netherlands. Calculations were made in similar fashion to others.[12-14] CSDH V was calculated using V rendering based on the following: (slice cross-sectional area of the largest V slice [typically the CSDH center]) × (number of slices) × (slice thickness [0.75 mm]). CSDH SA was calculated using the software surface rendering based on the following: (slice perimeter) × (number of slices) × (mean slice thickness [0.75 mm]). CSDH SA of the OM (SA_{OM}) was calculated by inputting only the OM perimeter of each slice (Figure 1).

Statistical Analysis

Between-group comparison was made using analysis of variance. Statistical significance was assessed as $P < 0.05$. Median Glasgow Coma Scale scores were calculated using a Mann-Whitney U test.

RESULTS

Sufficient data for analysis were available in 45 patients (surgical: n = 28; nonsurgical: n = 17) (Table 1). Risk factors for CSDH growth did not significantly differ between surgical and

Figure 1. Methodology. Chronic subdural hematoma (CSDH) margins were traced for individual slices from patient computed tomography brain scans using computer software. CSDH volume was calculated using volume rendering based on the following: (slice cross-sectional area of the largest volume slice [typically the CSDH center]) × (number of slices) × (slice thickness [0.75 mm]). CSDH surface area (SA) was calculated using the software surface rendering based on the following: (slice perimeter) × (number of slices) × (mean slice thickness [0.75 mm]). CSDH SA of the outer neomembrane was calculated by inputting only the outer neomembrane perimeter of each slice.