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Changes in splenic capsule with aging; beliefs and reality

Sara M. Higginson [a, b], Nicholas W. Sheets [a], Lawrence P. Sue [a], Mary M. Wolfe [a], Amy M. Kwok [a], Rachel C. Dirks [a], Reuben S. Doggett [c], Venu C. Gopal [d], James W. Davis [a, *]

[a] Department of Surgery, UCSF Fresno, 1st Floor Admin, 2823 Fresno Street, Fresno, CA, 93721, USA
[b] Regions Hospital Burn Center, 640 Jackson Street, St. Paul, MN, 55101, USA
[c] Retired - Sierra Pathology Associates, 305 Park Creek Dr, Clovis, CA, 93612, USA
[d] Chief Fresno County Coroner, 3150 East Jefferson Ave, Fresno, CA, 93725, USA

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ABSTRACT

Background: Research describing the splenic capsule and its effect on non-operative management of splenic injuries is limited. The aim of this study is to identify the current beliefs about the splenic capsule thickness and investigate changes in the splenic capsule with age.
Methods: Trauma Medical Directors were surveyed on their beliefs regarding splenic capsule thickness changes with age. Thicknesses of cadaveric splenic capsule samples were measured.
Results: The majority of trauma medical directors (59%) believe the capsule thickness decreases with age. There were 94 splenic specimens obtained. The splenic capsules of infants were thin and had a uniform layer of elastin fibers. With aging, the capsule becomes thick and develops a collagen layer.
Conclusion: Most trauma directors believe the splenic capsule thickness decreases with age. However, our results demonstrate that the splenic capsule thickness increases during childhood but remains constant in adulthood.

Introduction

Management of splenic trauma has been studied for decades, and non-operative management has become the standard of care over the last 3 decades.[1] Factors suggested to be involved in the failure of non-operative management have included hemodynamic instability, presence of contrast blush on CT and age.[2]

The success rate of non-operative management in pediatric patients has been reported as 98–100% compared to the lower adult rate of 80–90%.[2–4] Many believe that this difference in success is due to anatomic differences; specifically the long-held belief that the pediatric splenic capsule is thicker, and thus more resilient to trauma and more likely to be successfully managed non-operatively.[1,3,5–8] This belief has been echoed throughout literature and recited in even the most recent guidelines regarding splenic trauma developed by leaders in the field of trauma surgery.[1] However, primary research examining the splenic capsule is limited. Therefore, the aim of this study is to identify the current beliefs regarding the splenic capsule and investigate the changes in the splenic capsule with age.

Methods

Survey

The current beliefs on splenic capsule thickness were investigated by surveying Trauma Medical Directors from Level 1 and Level 2 Trauma Centers throughout the United States. This was a single-question survey asking the following: “Splenic capsule thickness: increases with age, stays unchanged with age, or decreases with age.” Survey responses were collected and managed using REDCap electronic data capture tools.[9]

Histological assessment

Cadaveric spleens were obtained from the Fresno County Coroner’s Office to investigate splenic capsule thickness over an age span of eight decades. Exclusion criteria included splenomegaly, chronic hemolytic disorders, lymphoma, leukemia, and splenic

* Corresponding author.
E-mail addresses: smhigginson@gmail.com (S.M. Higginson), nicholaswaynesheets@gmail.com (N.W. Sheets), lsue@fresno.ucsf.edu (L.P. Sue), mwolfe@fresno.ucsf.edu (M.M. Wolfe), akwok@fresno.ucsf.edu (A.M. Kwok), rdirks@communitymedical.org (R.C. Dirks), Venu.gopal@fresnosheriff.org (V.C. Gopal), jdavis@fresno.ucsf.edu (J.W. Davis).

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injury. Splenic capsules were sectioned then stained with hematoxylin and eosin and Verhoeff's elastic tissue stain. The thickness of the elastin and collagen-rich layers as well as the total splenic capsule thickness were measured in microns using light microscopy.

Statistical analysis was performed using one-way ANOVA and two-tailed independent t-tests. Data are expressed as mean ± standard deviation (SD) with significance attributed to $p < 0.05$. The surveys were administered following approval from the Institutional Review Board at Community Medical Centers and the splenic capsule analysis was deemed to be exempt.

Results

Surveys were sent to 223 Trauma Medical Directors and 102 (46%) responses were received. The majority (59%) answered that the splenic capsule thickness decreases with age, 25% believe it remains unchanged, and 16% replied that it increases with age.

There were 94 splenic specimens from the coroner's office that met criteria. The average age at death was 32 years (age range: 29 days–78 years) and 83% were male. Causes of death included trauma (65%), medical (26%), SIDS (6%), and other (3%).

Splenic capsules of infants were thin, dense, and had a uniform layer of elastin fibers (Fig. 1). The splenic capsule increased with aging, and developed two distinct layers, an inner elastin layer and an outer collagen layer (Fig. 2).

Splenic capsule and layer thickness were compared by age decile (Table 1). The collagen thickness increased from first to second ($p < 0.001$) and second to third age decile ($p < 0.001$). The elastin layer increased from first to second age decile ($p < 0.001$). The total capsule thickness increased from first to second age decile ($p < 0.001$) and again from second to third age decile ($p = 0.008$). When compared by age decile, no statistically significant differences in thickness existed after age 20 (Table 1). Correlations between age and splenic capsule thickness are shown in Fig. 3.

Discussion

Non-operative management has become increasingly common in the treatment of traumatic injuries of the spleen, as recent studies have shown that 95% of Grade 1 injuries and 90% of grade 2 injuries are successfully managed non-operatively.[2] Predictive factors for the failure of non-operative management have been described, with many reporting that adults are more likely to fail than pediatric patients. Failure of non-operative management is frequently attributed to differences in splenic capsule thickness, as literature often states that the pediatric splenic capsule is thicker, making the spleen more resilient to trauma.[1,5–7] This belief was demonstrated in our survey of Trauma Medical Directors, who are mostly fellowship-trained physicians working in university-affiliated institutions with a wealth of experience and expertise.[10] Of those responding to our survey, the majority agreed with the existing literature and responded that splenic capsule thickness decreases with age. This viewpoint may be rooted in the misinterpretation of a frequently cited paper by Gross in 1964.[6] This paper is referenced as stating that splenic capsule thickness decreases with age, but in fact suggests that the splenic capsule thickness increases until adulthood, then remains unchanged. The intention may have been lost in translation as it was originally written in German.[6,8,11]

Our findings contradict the belief that splenic capsule thickness decreases with age and demonstrates an increase in thickness until 20 years of age, at which point it remains constant. These findings align with those by Gross[6] as well as other recent studies.[12–14] With these findings, it now seems counterintuitive that a thinner splenic capsule would lead to improved non-operative outcomes. Therefore, additional factors, such as capsule composition and its relation to fracture patterns, may account for the improved non-operative outcomes of pediatric splenic trauma patients.

Our study identified an elastin rich layer in pediatric splenic capsules and a bilayer of an outer collagen layer surrounding an inner elastin layer in adults. Similar findings have been noted in previous studies and may be an important distinction accounting for the difference in non-operative outcomes in adults and pediatrics.[12,13] The pediatric spleen with an elastin rich capsule may be more compliant and therefore lead to improved outcomes. Even though the elastin layer does remain in the adult, the configuration appears more deranged as the elastic fibers become fragmented, coiled, shortened, and thickened as opposed to the pediatric elastin layer that is parallel and of regular shape.[13] Additionally, the collagen layer of adult splenic capsules adds rigidity to the spleen further reducing the compliance of the capsule. These anatomic differences may have downstream clinical effects. Biomechanical studies have shown the splenic capsule can undergo a larger amount of stress than the parenchyma and may act as the last barrier before uncontained rupture of the spleen.[15] Additionally, the pediatric spleen composition may cause it to fracture in a more favorable pattern. Clinical and animal studies of rhesus monkeys show that pediatric spleens typically fracture along the planes of segmental arterial branches and therefore demonstrate less blood loss and have greater likelihood of healing.[16,17]

Other differences, including mechanisms of injury and adult versus pediatric trauma centers may affect the outcomes among pediatric and adult patients. Previous studies have shown that in blunt trauma, approximately 42% of children are injured by low energy mechanisms such as falls or sporting injuries while 75% of adults are injured by high energy mechanisms such as motor vehicle crashes or motorcycle crashes.[8] While the incidence of

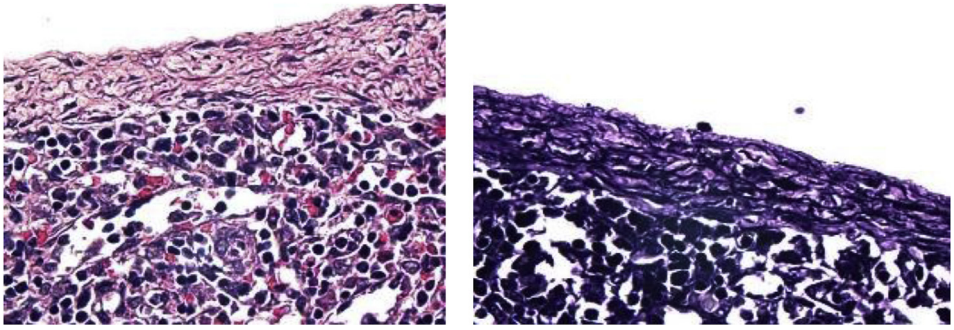

Fig. 1. Seven-month-old spleen with H&E stain (left) with thin, uniform capsule and with Verhoeff's elastic tissue stain (right) with single elastin layer forming the splenic capsule.

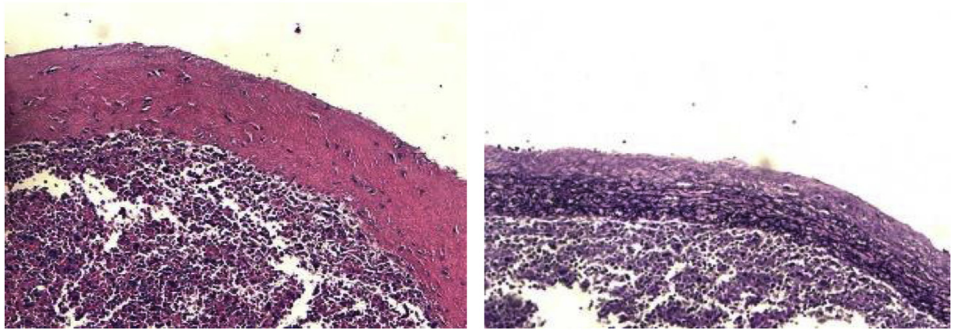

Fig. 2. Forty-nine-year-old with H&E stain (left) showing a thick capsule and with Verhoeff's elastic tissue stain (right) showing a bilayer of an inner elastin-rich layer and an outer elastin-poor/collagen-rich layer.

Table 1
Splenic capsule characteristics compared by age decile.

N	Age Decile								
	0–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80	P value
	15	16	19	14	9	11	7	3	
Thicness (μ)									
Collagen	5 ± 7	19 ± 7	30 ± 10	32 ± 11	36 ± 14	39 ± 12	35 ± 12	36 ± 10	<0.001
Elastin	34 ± 7	55 ± 18	58 ± 10	56 ± 16	57 ± 12	55 ± 17	60 ± 20	73 ± 44	<0.001
Total	39 ± 13	75 ± 18	89 ± 15	88 ± 16	92 ± 19	94 ± 24	96 ± 31	109 ± 51	<0.001

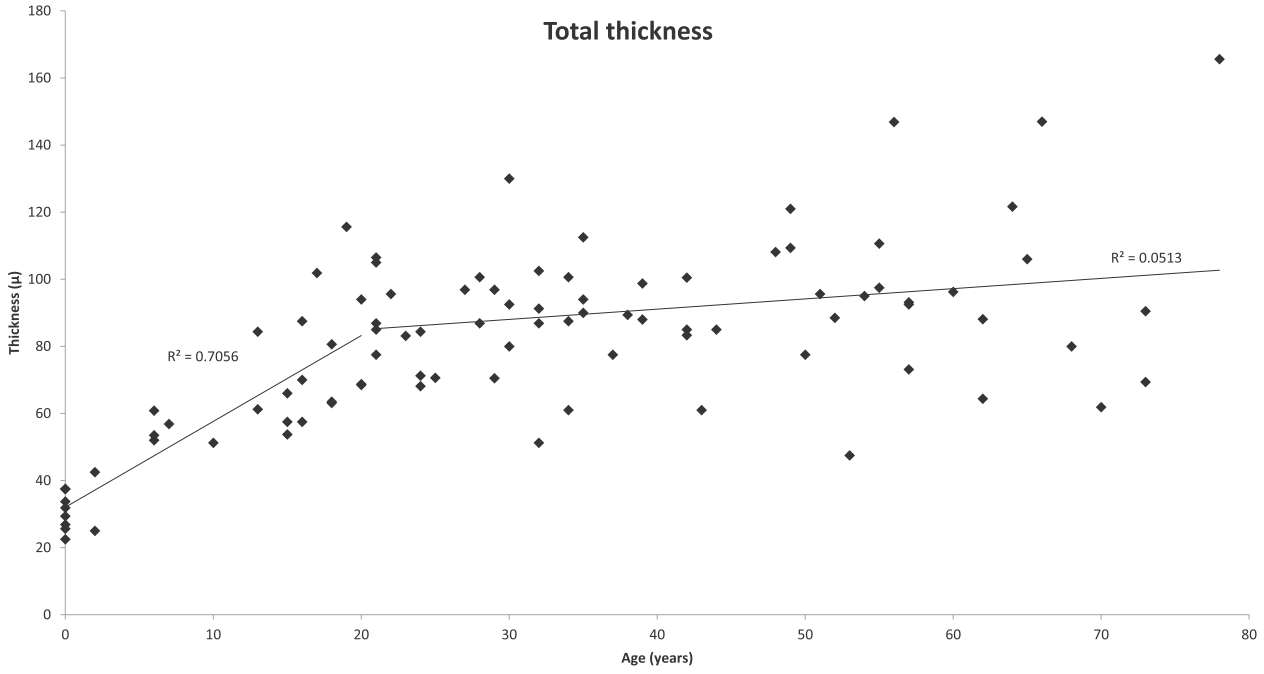

Fig. 3. Correlations between splenic capsule characteristics and age.

high-grade splenic injury presentations to trauma centers is similar between adults and pediatric patients, children have fewer associated injuries than adults, which may contribute to more successful non-operative management.[8,18] Additionally, higher splenectomy rates in pediatric patients have been noted at adult versus pediatric trauma centers.[18,19] Therefore, a combination of factors may account for better non-operative outcomes of pediatrics compared to adults.

This study has limitations including the response rate of the survey and the number of splenic specimens studied. Survey response rates vary in the literature, and ours at 46% is well within the accepted range.[20] The number of specimens in the 60–80 year age range was less than the other age groups. One of the 71–80 year specimens had an increased capsule thickness and may have been an outlier. Additional research regarding biomechanics of splenic capsule injury with age may help identify explanations for improved outcomes among pediatric splenic trauma compared to adults.

Conclusion

The majority of Trauma Medical Directors across the United States believe splenic capsule thickness decreases with age or stays the same. This research demonstrates that the splenic capsule becomes thicker with age until approximately 21 years and develops a bilayer capsule consisting of collagen and elastin. These findings may shed light behind the improved non-operative outcomes of pediatric splenic trauma compared to adults.

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