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SPINE

Correlation of Soft tissue Projection in Injured NEcks (CSPINE)

Prevertebral soft tissue measurement in paediatric cervical spine trauma

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Abstract

Background: In paediatric trauma, measured increase in prevertebral soft tissue thickness on a lateral cervical spine (C-spine) X-ray is interpreted as swelling, raising suspicion of C-spine injury. Defining swelling in absolute measurements is cumbersome – children's sizes vary. Published recommendations are largely lacking in evidence. There may be potentially more consistent tools, for example, to measure soft tissue thickness as a ratio of vertebral body width. The aim of this study was to determine whether consistent, measurable prevertebral soft tissue to vertebral body width ratios exist for use as simple diagnostic tools in the assessment of swelling and injury in paediatric C-spine trauma.

Patients and methods: C-spine trauma X-rays taken at a South African children's hospital were randomly sampled. Seventy-one un-intubated X-rays from 85 controls were used to identify normal ratios. The authors measured vertebral bodies and soft tissue at each level, created all possible ratios, then chose the two least variable – one for the upper and one for the lower C-spine. Twenty cases aided in determining diagnostic accuracy for C-spine injury.

Results: Mean soft tissue at the second cervical vertebral level (c2) was 38% of the seventh vertebra (C7) (95% confidence interval [CI]: 34–41.9%, standard error [SE]: 2.0%). Mean c6 soft tissue was 65.6% of C7 vertebra (95% CI: 61.9–69.3%, SE: 1.9%). In diagnosing C-spine injury, a receiver operating characteristic (ROC) curve calculation gave an empirical optimal cut-point of 53.9% and 74.4% respectively. Using practical cut-offs of 55% at c2 and 75% at c6 yielded specificities of 93.8% (95% CI: 84.8–98.3%) and 81.8% (95% CI: 70.4–90.2%), with negative predictive values of 90.9% (95% CI: 81.3–96.6%) and 91.5% (95% CI: 81.3–97.2%) respectively.

Conclusion: Consistent and specific ratios exist in the upper and lower paediatric C-spine. Both ratios have poor sensitivities and positive predictive values and so are poor screening tools; however, a positive result can raise suspicion of C-spine injury in high-risk individuals. This can help to motivate for further investigations such as computer tomography (CT) or magnetic resonance imaging (MRI), which may not be easily accessible in under-resourced settings. However, further research is required to validate the diagnostic value of these ratios.

Level of evidence: Level 4

Keywords: prevertebral soft tissue, vertebral body width, cervical spine, paediatric, C-spine trauma, ratio

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Conflict of interest: All authors declare that they have no conflict of interest with respect to this article.

Introduction

Paediatric cervical spine (C-spine) injury is rare but potentially devastating.[1] Although soft tissue swelling on X-ray has been referred to as an aid in identifying injury,[1,2] published measurement methods and recommendations on what constitutes swelling vary, as does the diagnostic significance of said swelling.[3-16] Measurements in millimetres (mm) may not be applicable across wide age ranges and an alternative is measurement as a ratio of vertebral body width. Some published normal values are based on primary evidence, but many statements regarding measurement norms are uncited, or citations do not correctly support the measurement.[3-15] *Table I* provides a summary of published normal values.

The purpose was to determine whether measurement of prevertebral soft tissue as a ratio of vertebral body width on paediatric lateral C-spine trauma X-rays is consistent in uninjured, un-intubated patients and, as a secondary objective, is of diagnostic value in identifying C-spine injury. The hypothesis was that one such measurement would be identified for the upper and one for the lower C-spine; that these would have clinically acceptably narrow variability across age groups and sexes; and that measurements greater than these would correlate with C-spine injury.

Other secondary objectives were to describe the atlanto-dens interval (ADI), basion-dens interval (BD) and effect of intubation on soft tissue thickness.

Materials and methods

Study design and setting

A retrospective pragmatic quantitative cross-sectional study randomly sampled digital lateral C-spine X-rays taken in patients under 13 years of age at Red Cross War Memorial Children's Hospital in Cape Town, South Africa, between December 2012 and February 2016. All X-rays were assigned consecutive numbers, then selected according to a computer-generated random number sequence. X-rays taken for non-traumatic reasons were excluded. Additional X-rays of injured patients from pre-existing records and from the same period were added to the random sample to increase the number of injuries available for analysis to complete the secondary objectives. Patient folders were reviewed. No follow-up was performed.

Dedicated erect or supine lateral C-spine views on conventional, mobile unit and whole-body low dose digital X-rays (LODOX) of patients both with and without C-spine injury were included. Patients assessed as being clinically clear according to the Canadian C-spine,[17] National Emergency X-Radiography Utilization Study Group (NEXUS)[18] or other pragmatic criteria and that were finally managed and discharged as having no C-spine injury were classified as controls. Patients with normal C-spine X-ray, computerised tomography (CT) scan or magnetic resonance imaging (MRI) report were also classified as controls. Patients with bony, ligamentous, cervical cord or cervical nerve injury clinically or on imaging were classified as cases. There were 85 controls and 20 cases.

Measurements

Measurements were performed in mm up to one decimal point using the ruler tool of the Phillips iSite® Enterprise radiology system. If an area could not be visualised, those specific measurements only (28 out of 1 365 possible measurements) were treated as missing data.

Soft tissue thickness was measured parallel to the adjacent vertebral body's inferior endplate, from the most anterior–inferior aspect of that vertebral body to the most anterior edge of the tissue shadow. As the first cervical vertebra (C1) has no body, measurement started from the most anterior inferior aspect of C1's anterior arch to the anterior edge of the soft tissue, along a line extended from the most inferior projections of C1 anterior and posterior arches. The soft tissue measurements were labelled c1–c7 according to the adjacent vertebra. In intubated cases, if the anterior edge of the soft tissue shadow was obscured by the tube, the measurement was taken up to the most posterior edge of the tube.

Vertebral body width was measured from the most posterior–inferior corner to the most anterior–inferior corner and labelled C2–C7. Atlanto-dens interval (ADI) was measured as drawn from the posterior inferior corner of the anterior arch of C1 to the adjacent anterior border of the odontoid, along the line between the most inferior projections of C1 anterior and posterior arches. Basion-dens distance (BD) was measured from the anterior rim of the foramen magnum to the most prominent superior projection of the dens. See *Figure 1* for measurement examples.

The age of the patient was extrapolated from the dates of birth and of the X-ray. Sex was recorded for all patients and, where available, weight in kilograms up to one decimal point. Mechanism of injury was extracted from the clinical information.

Digital radiology reports attached to X-ray, CT and MRI images were examined and any comments on soft tissue and adequacy of images noted. It was recorded whether an injury was identified, excluded or unclear. This was correlated with clinical information regarding examination and management.

Blinding during measurement was not possible as clinical information was digitally linked to images; however, strict measurement protocols as above minimised risk of bias. A single author measured all images.

Statistical methods

A sample size of 60 for the primary objective was calculated by hypothesising clinically acceptably accurate ratios and confidence

Table I: Published normal values for prevertebral soft tissue in children

(A lowercase measurement, e.g. c4, refers to the thickness of soft tissue adjacent to the numbered cervical vertebra – in this case, fourth. An uppercase measurement, e.g. C5, refers to the width of the numbered cervical vertebra – in this case, fifth)

Type of measurement	Recommendation	Source	Evidence base
Ratios in children (age in years)	Post-pharyngeal tissue (c4): 1.5 C5 (age 0–1) 0.5 C5 (age 1–3) 0.4 C5 (age 3–6) 0.3 C5 (age 6–14) Post-ventricular soft tissue (c5): 2.0 C5 (age 0–1) 1.5 C5 (age 1–2) 1.2 C5 (age 2–14)	Hay[3] (as re-drawn in Keats and Lusted[4])	Measurements of 25 paediatric C-spine X-rays
	c2 = 0.3 C3 c6 = C6	Hoffman and Dix-Peek[5,6]	No base of evidence found: statement of measurement unexplained and not cited by authors
	c1–4 = <0.5 adjacent vertebra c5–7 = adjacent vertebra	Di Mascio and Sivaraman[7]	No base of evidence found: statement of measurement unexplained and not cited by authors
	Below cricoid cartilage ≤ 0.75 adjacent vertebra	Phelps[8]	No base of evidence found: statement of measurement unexplained and not cited by authors. Possibly also applied to adults
	c3 ≤ 0.33–0.5 C3 c5 is ≤ 1.25 C5 or C6	Baren *et al.*[9]	No base of evidence found: statement of measurement unexplained and not cited by authors
	Retropharyngeal tissue ≤ adjacent vertebra Retropharyngeal abscess only when retropharyngeal tissue = 2× adjacent vertebra	Yeoh *et al.*[10]	First measurement: incorrect citation (no such measurement mentioned in the references listed). Second measurement: possibly based on measurements in cases of retropharyngeal abscess in nine paediatric (< 6 years old) C-spine X-rays. No actual measurements quoted or analysed in the original text
	Retropharyngeal tissue = 0.5–0.66 adjacent vertebra	Egloff *et al.*[11]	Incorrect citation (no such measurement mentioned in the references listed)*
Absolute measurements in children	c2 upper limit = 7 mm c6 upper limit = 14 mm	Wholey *et al.*[12]	Measurements of 120 normal paediatric (< 15 years old) C-spine X-rays
	c3 < 6 mm c6 < 14 mm	Warner and Hedequist[1]	No base of evidence found: statement of measurement unexplained and not cited by authors
	c3 ≤ 5–7 mm c5 ≤ 14 mm	Baren *et al.*[9]	No base of evidence found: statement of measurement unexplained and not cited by authors
	Mean retropharyngeal tissue = 6.2 mm (infant) Mean retrotracheal tissue = 9.2 mm (preschool children)	Haug *et al.*[13]	Measurements of 86 normal paediatric and adult C-spine X-rays (results stratified to age groups)
	Soft tissue (rounded to nearest 0.1 mm) at c2, c5 and c6 for age groups (in years): Age 0–1: c2 = 4.5–10.5 c5 = 9.2–12.6 c6 = 7.7–13 Age 1–2: c2 = 4.1–12.2 c5 = 6.6–9.7 c6 = 4.7–9.6 Age 2–3: c2 = 3.7–4.3 c5 = 7.9–13.2 c6 = 9.2–10.6 Age 3–6: c2 = 3.7–6.6 c5 = 4.5–13.4 c6 = 3.8–10.2 Age 6–14: c2 = 3.7–7.7 c5 = 7.8–16 c6 = 6.1–14.8	Reyes *et al.*[14]	Measurements of 50 normal paediatric (0–14 years old) C-spine X-rays
	Mean c3 (similar at c2 and c4) = 3.7 mm - 0.02 × age (years) + 0.01 × weight (pounds)	Sistrom *et al.*[15]	Measurements of 227 randomly selected normal paediatric and adult (age 8–97 years) C-spine X-rays. Formula based on stepwise regression model. Also applicable to adults
	Above cricoid cartilage ≤ 4 mm after the age of 2 or 3 years	Phelps[8]	No base of evidence found: statement of measurement unexplained and not cited by authors, possibly also applied to adults

* One citation listed could not be accessed at time of publication

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Figure 1. Measurements on X-ray

Solid arrows are measurement lines for:
BD
ADI
c1 soft tissue
c2 soft tissue
c6 soft tissue
C7 vertebral body
Dashed lines are guides for measurement lines

intervals: a 99% confidence interval (CI) of ±15% around a hypothesised mean of 90% and standard deviation (SD) of 45% was considered sufficient, based on anticipated estimated minimum and maximum values of 20% and 200%. Random sampling was performed until 60 uninjured, un-intubated patients were identified. During this phase 13 intubated patients were also sampled as they were randomly interspersed. Random sampling then continued until another two un-intubated (and one intubated) patients were added. Due to counting error, 11 un-intubated patients were added. Provisional data analysis was performed before and after the sample was enlarged. Repeat data analysis failed to show a clinically significant difference in the consistency of measurements after the increase of the sample size, so it was concluded that further enlarging the sample was unlikely to change final results and so data collection was concluded. Twenty injured patients were captured during random sampling as well as additions from pre-existing records.

Data management and analysis was conducted in Stata 14. Simple descriptive statistics were used for demographic data. Age was grouped into categories according to international conventions.[19,20] The primary outcome was reported using means and 95% CIs. The appropriate parametric and non-parametric tests were used and a p-value of <0.05 was considered statistically significant. Ratios for every soft tissue thickness to every vertebral body width (42 ratios) were created in un-intubated controls. Two ratios with the lowest standard error (one for upper and one for lower C-spine) were defined as the most consistent. In determining diagnostic accuracy of soft tissue swelling to predict presence of injury, these ratios of cases and controls (in un-intubated patients) were correlated to injury using point-biserial correlation. In addition, receiver operating characteristic (ROC) analysis was used to compare these ratios to aid in identifying the optimal empirical diagnostic cut-point. A sensitivity analysis was conducted by excluding poor quality X-rays. Missing data was excluded.

Results

A total of 2 570 C-spine X-rays were digitally accessible, of which 893 were conventional or mobile C-spine X-rays and 1 731 were LODOX, including dedicated lateral C-spine views. During random sampling, 48 X-rays taken for non-traumatic reasons were excluded. Four patients with injury were identified by chance and added to the 16 known cases (*Figure 2*). *Table II* provides a summary of demographic data.
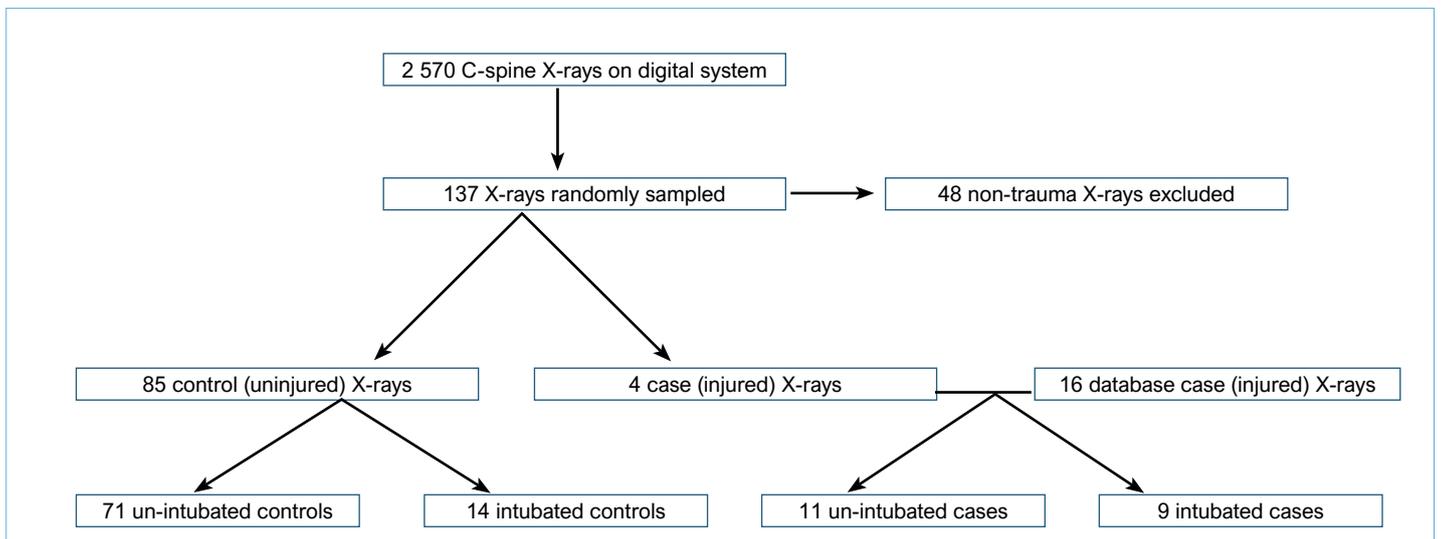
Figure 2. Sampling of X-rays

Table II: Sample demographics

	Controls n (%)	Cases n (%)
Sex		
Male	60 (70.6)	18 (90)
Female	25 (29.4)	2 (10)
Age		
0–1 month	0 (0)	0 (0)
1 month–2 years	10 (11.8)	0 (0)
2–6 years	38 (44.7)	13 (65)
6–12 years	35 (41.2)	7 (35)
12–18 years	2 (2.3)*	0 (0)
Mechanism of injury		
Pedestrian vehicle accident	56 (65.9)	10 (50)
Motor vehicle accident	7 (8.2)	8 (40)
Fall from height	12 (14.1)	1 (5)
Fall from same level	4 (4.7)	0 (0)
Blunt trauma	3 (3.5)	1 (5)
Crush	1 (1.2)	0 (0)
Bicycle to car	1 (1.2)	0 (0)
Unknown	1 (1.2)	0 (0)
Intubation status		
Not intubated	71 (83.5)	11 (55)
Intubated	14 (16.5)	9 (45)
Type of injury		
Upper cord oedema/contusion	n/a	5 (25)
Cord transection at medulla oblongata	n/a	1 (5)
Atlanto-occipital dissociation	n/a	3 (15)
Upper spine ligamentous injury	n/a	1 (5)
C1/2 subluxation	n/a	1 (5)
Dens fracture	n/a	3 (15)
C1 lamina/anterior arch fracture	n/a	1 (5)
C2 fracture	n/a	1 (5)
Cord oedema/contusion C3–T2	n/a	1 (5)
C3/4 unifacet dislocation	n/a	1 (5)
C6/7 dissociation (100% anterolisthesis)	n/a	1 (5)
C7/T1 fracture-dislocation	n/a	1 (5)

* Both patients were under 13 years of age and were analysed together with the 6–12 years group during subgroup analysis.

The ADI was measurable in 78 controls and the mean was 2.6 mm (SD 1.1). ADI was measurable in all 20 cases and had a mean of 3.6 mm (SD 3.3). BD was measurable in 48 controls and had a mean of 9.4 mm (SD 2.8). BD was measurable in 13 cases with a mean of 11.3 mm (SD 5.8).

Main outcome results

The soft tissue/vertebral body ratio for the upper C-spine with the lowest variance in un-intubated controls was c2/C7, with mean c2 soft tissue being 38% of C7 vertebra (95% CI: 34–41.9%, SE: 2.0%, variance: 2.5%). For the lower C-spine the most consistent ratio was c6/C7 with mean c6 soft tissue being 65.6% of C7 vertebra (95% CI: 61.9–69.3%, SE: 1.9%, variance: 2.3%). As sensitivity analysis, excluding X-rays reporting that the neck was flexed or the patient was crying, resulted in more precision and very slightly lower mean in c2/C7 (2% less) but no clinical or statistical difference. For these reasons, and as the study is pragmatic, it was decided to keep these X-rays in the overall analysis. In the study sample, those poor X-rays were not repeated before further clinical decisions were made. See *Table III* for a summary of these ratios in different patient groups.

Secondary outcome results: correlation and diagnostic accuracy

Soft tissue ratios at c2 and c6 in un-intubated controls were compared to un-intubated cases to determine correlation between soft tissue thickness and presence of injury. The point-biserial correlation coefficient for c2/C7 was 0.3060 (p-value: 0.0085) and for c6/C7 was 0.1059 (p-value: 0.3660) (*Figure 3*).

Soft tissue thickness at these levels (as a ratio of C7 vertebra) in un-intubated controls was again compared to un-intubated cases to determine cut-off points with optimal sensitivity and specificity to diagnose C-spine injury. Most importance was placed on specificity. ROC curve calculation gave empirical optimal cut-points of 53.9% for c2/C7 and 74.4% for c6/C7. To create a clinically practical and easy-to-remember 'CSPINE rule' (**C**orrelation of **S**oft Tissue **P**rojection in **In**jured **Ne**cks), these values were rounded up to a cut-off of 55% at c2 and 75% at c6, which yields specificity of 92.3% (95% CI: 83–97.5%) and 81% (95% CI: 70.4–90.2%) respectively, with negative predictive values of 90.9% (95% CI: 81.3–96.6%) and 91% (95% CI: 81.3–97.2%). See *Table IV* for a summary of the diagnostic test characteristics and *Figure 4* for the ROC curve.

Table III: c2/C7 and c6/C7 ratios in subgroups

	c2 soft tissue as % of C7 vertebra*	c6 soft tissue as % of C7 vertebra*
No C-spine injury (n=85)	42.7 (37.4–48)	62.2 (58.3–66.1)
Not intubated (n=71)	38 (34–41.9)	65.1 (61.5–68.8)
Intubated (n=14)	65.9 (44.5–87.3)	44.9 (34.6–55.2)
C-spine injury (n=20)	65.2 (48.5–81.1)	59.3 (47–71.6)
Not intubated (n=11)	56.3 (33.5–79)	71 (54.6–87.3)
Intubated (n=9)	74.0 (50–98)	47.7 (32.2–63.2)

* Means and 95% CIs

Table IV: Test characteristics of the CSPINE rule

c2/C7 <55%:	Sensitivity 33.3% (95% CI 7.5–70.1%) Specificity 93.8% (95% CI 84.8–98.3%) PPV* 42.9% (95% CI 9.9–81.6%) NPV* 90.9% (95% CI 81.3–96.6%)
c6/C7 <75%:	Sensitivity 44.4% (95% CI 13.7–78.8%) Specificity 81.8% (95% CI 70.4–90.2%) PPV* 25% (95% CI 7.27–52.4%) NPV* 91.5% (95% CI 81.3–97.2%)

* PPV: Positive predictive value; NPV: Negative predictive value
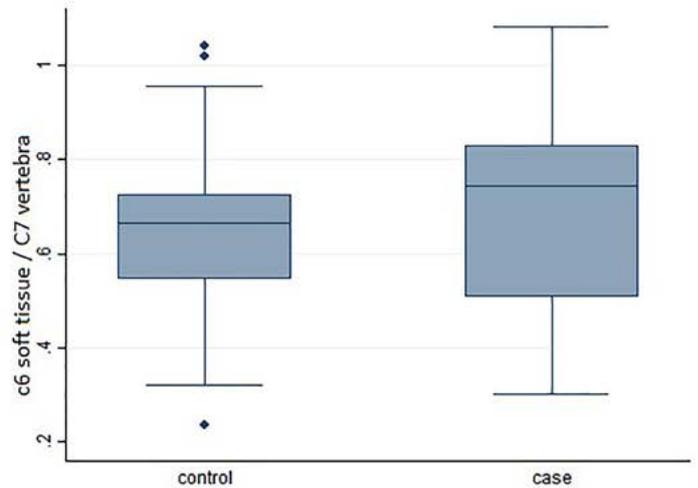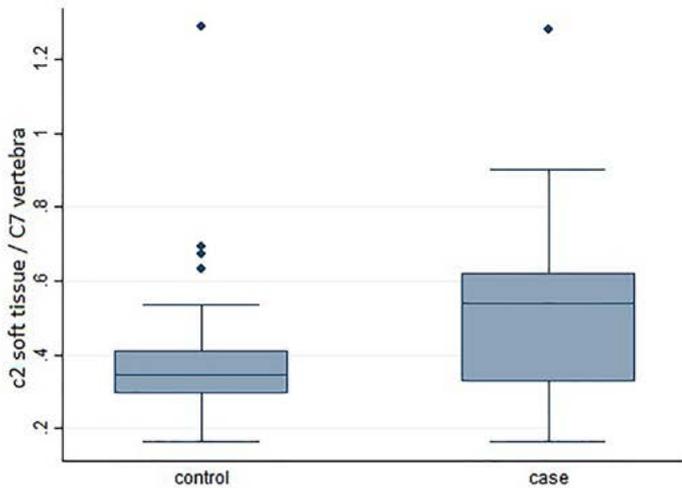
Figure 3. c2/C7 and c6/C7 in un-intubated controls and cases

Table V: Soft tissue thickness in intubated vs un-intubated control patients

Soft tissue thickness (as a percentage of C7 vertebra)	Un-intubated mean (SD)	Intubated mean (SD)	p-value*
c1	55.6 (38.1)	109.6 (82)	0.0213
c2	38 (15.8)	65.9 (38.9)	0.0098
c3	48 (28)	67.2 (29.7)	0.0239
c4	68.4 (24.8)	64.3 (23)	0.2926
c5	73.5 (18.4)	53.5 (19.8)	0.0005
c6	65.6 (15.1)	44.9 (18.7)	0.0006
c7	52 (22.2)	39.9 (17.5)	0.0445

* Despite some ratios being normally distributed and others not, for the sake of consistency with other tables the mean is reported. However, p-values for the Wilcoxon rank-sum test are reported for all variables in this table as it provided the more conservative measure of significance compared to the t-test. Both tests also had the same result for significance or non-significance except c7, but as it followed the general trend it was assumed to be significant.

Table VI: c2/C7 and c6/C7 by age groups (un-intubated controls)

	c2 soft tissue as % of C7 vertebra*	c6 soft tissue as % of C7 vertebra*
Infants (1 month–2 years)	46.3 (38.2–54.5)	57.6 (36.2–78.9)
Young children (2–6 years)	41 (32.6–49.4)	68.1 (62.1–74.2)
Older children (6–13 years)	34 (30.7–37.2)	64.1 (60.4–67.8)

* Means and 95% CIs

Secondary outcome results: effect of intubation on soft tissue thickness

Soft tissue at each level was, for convenience, expressed as ratios of C7 vertebra and compared between un-intubated and intubated patients (*Table V*).

Subgroup and confounder analysis

Subgroup analysis was performed for infants (1 month–2 years), young children (2−6 years) and older children (6–13 years). See
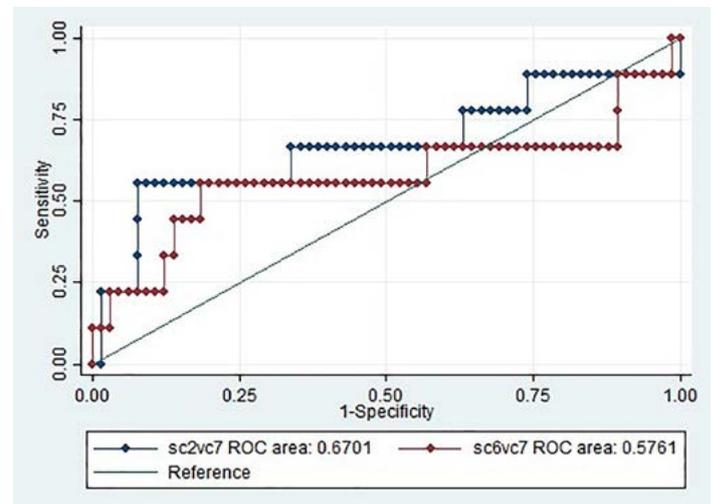
Figure 4. ROC curves for c2/C7 and c6/C7

sc2vc7: soft tissue of c2 as a ratio of C7 body; sc6vc7: soft tissue of c6 as a ratio of C7 body

Table VI for a summary of c2/C7 and c6/C7 in un-intubated control patients in these age groups.

Weight was available for 36 patients. The correlation coefficient for weight compared to soft tissue thickness in un-intubated control patients was -0.2111 (p-value 0.3582) for c2/C7, and -0.3056 (p-value 0.1667) for c6/C7.

Discussion

In our sample of un-intubated, uninjured patients, very consistent soft tissue to vertebral body ratios for both the upper and lower C-spine could be selected. Both were normally distributed and CIs were much narrower than anticipated as acceptable in the sample size calculation hypothesis. At c2, mean soft tissue was 38% of C7 vertebra (95% CI: 34–41.9%) and c6 was 65.6% of C7 vertebra (95% CI: 61.9–69.3%). The serendipitous fact that both ratios with least variability have C7 as denominator makes them extremely convenient. It also indirectly reinforces the need for adequate C-spine X-rays, i.e. where the C7 and first thoracic vertebra interface is visible.

The upper C-spine ratio, c2/C7, was significantly larger in injured compared to uninjured patients regardless of intubation status. When considering only un-intubated patients, this increase was

more marked, with a statistically significant correlation coefficient of 30.6% (moderate positive relationship). The lower C-spine ratio, c6/C7, was not significantly different between uninjured and injured patients, even when considering only un-intubated patients. The slight trend towards larger mean soft tissue in injured patients had a statistically non-significant correlation coefficient of 10.6% (weak positive relationship). The fact that upper C-spine swelling correlated more with injury than lower C-spine swelling is likely since most injuries in our sample were in the upper C-spine. This injury pattern is consistent with international literature.[21]

When testing sensitivity and specificity with the ROC curve, the mean value of c2/C7 at 38% scored poorly with a sensitivity of 66.7% and specificity of 60.9%. Even using the upper limit of the CI, 41.9%, resulted in improving specificity only to 76.6% at the cost of dropping sensitivity to 55.6%. The ROC curve was used to calculate the optimal cut-point for specificity, as C-spine X-rays are not screening tests for the general population – they should be diagnostic tests for patients already screened and suspected of C-spine injury by history and examination. The calculated optimal cut-point of 53.9% provided specificity of 94% without worsening sensitivity further. Rounding up to a more memorable 55% (or even 54%) unfortunately dropped sensitivity down to the next bracket (33.3%). However, CIs for sensitivity are extremely wide due to low prevalence of injury, so the drop is statistically non-significant. The decision was made to suggest the 'CSPINE' rule that c2 soft tissue should be less than 55% of C7 vertebra. The method to develop the CSPINE rule suggesting that c6 soft tissue should be less than 75% of C7 vertebra followed similar patterns. DeBehnke and Havel[22] employed comparable methodology in adults and found similar patterns but did not accept any point on the ROC curve as adequate. Patel *et al.*[16] also demonstrated similar high specificities and low sensitivities in testing adults using the '7 mm at C2 and 2 cm at C7' rule.

Both ratios have extremely poor sensitivities, and are therefore poor screening tools, but can aid in ruling on injury in patients with high clinical suspicion of injury due to high specificity. The good negative and poor positive predictive values reflect low prevalence of injury.

Intubation in uninjured controls clinically and statistically significantly increased soft tissue thickness in the upper C-spine (c1–3). At c4 there was no difference. Below c4 intubation significantly decreased soft tissue thickness. The lack of difference at c4 is possibly due to the inherent anatomic variability at the level of c4 (location of the glottis), or due to its fulcrum-like mid-position in the trend of upper C-spine tissue increasing and lower C-spine tissue decreasing after intubation. In injured patients, the effect of intubation at c2 and c6 followed the same trend, but without statistical significance. These findings in the upper C-spine are similar to Di Mascio and Sivaraman's[7] findings in adults, but the trend of decreased soft tissue thickness below c4 is in contrast to their findings of no difference.

Univariate analysis determined whether weight or age confounded soft tissue thickness. Weight was unavailable in about two-thirds of patients, possibly due to difficulties in placing polytraumatised patients on scales. In our sample, weight and soft tissue thickness had a weak negative correlation but without statistical significance.

Age had no effect on c6/C7, as evidenced by overlap of all three CIs for available age groups. At c2, however, there seemed to be a trend towards decreasing soft tissue thickness as age increased. CIs overlapped between infants and young children, and between young and older children, but were statistically different with no overlap between infants and older children. These, however, come very close to overlapping, with the upper limit in older children being 37.2% and the lower limit in infants being 38.2%. As these values are so close to the all-ages mean it was decided that

difference between ages was not clinically significant. The finding of single useful ratios across age groups is in contrast with Hay's[3] recommendations which differ between age groups.

Testing diagnostic accuracy and development of the optimal cut-point as a rule in diagnosing C-spine injury were secondary objectives, thus the sample size was not designed for that purpose. The study was powered to measure normal values for soft tissue thickness in uninjured, un-intubated patients. The study sample consisted of a much smaller group of cases than controls. This, however, is more closely representative of clinical practice where C-spine injury has relatively low prevalence, and as this is a cross-sectional study, it was considered a minor limitation. In addition, the specificities have acceptably narrow CIs to be of clinical use. There would need to be 95 cases in order to determine similarly narrow intervals for sensitivity, and there has anecdotally not been that many cases in the history of the hospital since their introduction of digital X-rays. The areas under the curve for the two diagnostic ratios are 0.67 (upper C-spine) and 0.58 (lower C-spine), which shows that prevertebral soft tissue swelling does not have good discriminative value for predicting soft tissue injury, especially in the lower C-spine.

There were only four lower C-spine injuries and they were not specifically sub-analysed. No recommendation can therefore be made regarding the use of these findings in patients with lower C-spine injuries as such. Comments and conclusions about diagnostic accuracy of the CSPINE rule and correlation of soft tissue thickness with presence or absence of injury in this study refer only to the possibility of injury somewhere in the C-spine rather than being directly related to an anatomical area. There is potential for further research in the diagnostic value of these ratios in different types of paediatric C-spine injuries, and validation of the ratios with further research that includes more cases of injury. This further research may help clarify if prevertebral soft tissue swelling should form part of the consideration in assessing for C-spine trauma in children.

The findings are for children between the ages of 1 month and 13 years and may not be generalisable to neonates, adolescents or adults.

Conclusion

This study demonstrates that there are consistent normal values when measuring prevertebral soft tissue thickness as a ratio of vertebral body width in un-injured, un-intubated paediatric patients: soft tissue at c2 and c7 should be 38% and 65.6% of C7 vertebral body, respectively.

However, soft tissue measurement itself does not seem to be very sensitive in predicting injury. A more specific 'CSPINE rule' (soft tissue at c2 and c6 should be less than 55% and 75% of C7 vertebral body, respectively) can be followed. A positive result would raise suspicion of C-spine injury in high-risk individuals and can help to motivate for further investigations such as CT or MRI, which may not be easily accessible in under-resourced settings. However, further research is required to validate the diagnostic value of these ratios.

Ethics statement
Prior to commencement of the study ethical approval was obtained from the following ethical review board: University of Cape Town Health Research Ethics Committee (reference number HREC: 118/2016).

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No identifying information for any patient is included in this article. No human subjects were directly involved as it was a review of existing medical records.

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