A radiographic assessment of the distances from the sacral hiatus to the lower lumbar spinous processes

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Summary

The objective of this work is to determine whether the linear distances from the sacral hiatus to the lower lumbar spinous process are normally distributed when measured on Magnetic resonance images. In an observational study the distance from the sacral hiatus to the inferior border of the lower lumbar spinous processes was measured and analysed in sixty nine subjects on sagittal magnetic resonance images of the pelvis.

Analysis of all distances with the Anderson-Darling Normality test showed the distances from the sacral hiatus to the 4th and 5th lumbar spinous processes to be normally distributed. The distances in males and females from the sacral hiatus to the fifth lumbar spinous process were 83.0 (13.7) mm and 71.0 (12.7) mm, respectively. The distances in males and females from the sacral hiatus to the fourth lumbar spinous process were 101.6 (14.2) mm and 92.2 (11.6) mm respectively. A significant inverse correlation between age and distance from the sacral hiatus to the 5th lumbar spinous processes was found in males in a magnetic resonance study. The distances from the sacral hiatus to the 4th and 5th lumbar spinous processes are normally distributed. These preliminary data may help to develop techniques to help prevent the neurological injury associated with neuraxial injections.

Key words: Lumbar puncture – Spinal cord – Magnetic resonance – Tuffier's line

Introduction

Procedures necessitating lumbar puncture (LP) are common in clinical medicine. These include spinal anaesthesia, diagnostic LP, intrathecal chemotherapy and myelography. The risk of spinal cord damage associated with LP is rare but the associated neurological deficit can be devastating and permanent. Reynolds (2001) has described seven cases of conus medullaris damage post spinal anesthesia. Auroy et al. (1997) found an incidence of neurological deficit post spinal anaesthesia of six per 10,000. Whereas this is one of many studies reporting the incidence of neurological injury associated with neuraxial anaesthesia, it is difficult to find similar data on lumbar puncture in the hands of non-anaesthetists. The incidence of this would appear to remain unknown.

Spinal cord injury may be a consequence of direct cord trauma but can also occur due to spinal haematoma formation. Bills et al. (1991) proposed that puncture of the artery of Adamkievicz may result in spinal haematoma.

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The location of this artery has been studied by Takase et al. (2002) and found to normally occur at the level of the high lumbar or thoracic vertebrae. However, Bills (1991) stated that rarely it can be found as low as the fifth lumbar vertebra and hence may be punctured during LP. A major contribution to the risk of spinal cord injury has been the difficulty in identifying the level of a given palpable lumbar interspace. There is no reported clinical method to distinguish one interspace from its neighbours. Currently, Tuffiers's line is used to try to locate the 4^{th} lumbar spine (Aitkenhead and Smith, 1996) but this is now known to be unreliable since Broadbent (2000) demonstrated that clinicians using Tuffier's line as a landmark are regularly mistaken as to which lumbar interspace they are palpating. Although the conus medullaris typically lies at the level of the first lumbar vertebra work by Saifuddin et al. (1998), McDonald et al. (1999) has shown that its position varies from the middle third of the body of the 11^{th} thoracic vertebrae to the middle third of the body of the third lumbar vertebra. Therefore, LP below the third lumbar spine will avoid direct spinal cord injury and is unlikely to cause an arterial haematoma. Lumbar puncture at or above this level has been criticized as being unsafe (Reynolds, 2000). Unfortunately this will inevitably occur unintentionally as no clinical method of preventing it is available. The distances from the sacral hiatus (SH) to the third, fourth and fifth lumbar spinous processes (LSP) have not been described. If the distances from the SH to the LSP's were normally distributed then it may be possible to use these data to improve the probability of entering the spinal canal below a given LSP; e.g. the mean distance minus 3 standard deviations (SD) should confer 99.6% certainty of this. Of particular importance is the third lumbar spine, as the conus medullaris does not normally extend below this spine. In this way the risk of spinal cord injury may be lowered. The aim of this study was to determine whether or not the distances from the SH to the lower LSP's when measured on MR images are normally distributed and to make a preliminary record of the distances measured to assist with the preparation of a larger definitive study.

Materials and Methods

A retrospective study of pelvic MR scans was performed. Exclusion criteria were spinal fracture, collapse or deformity, dwarfism or age less than 18 years.

Seventy-four pelvic MR scans were retrieved from the MR scanners records (this was the total number of pelvic scans since installation). Measurements from the SH to the lower LSP's were possible on a sagittal section of 69 scans where the anatomical landmarks were identifiable. Five of 74 scans were unsuitable for analysis as the sacral hiatus could not be seen. The images were made anonymous apart from sex and age.

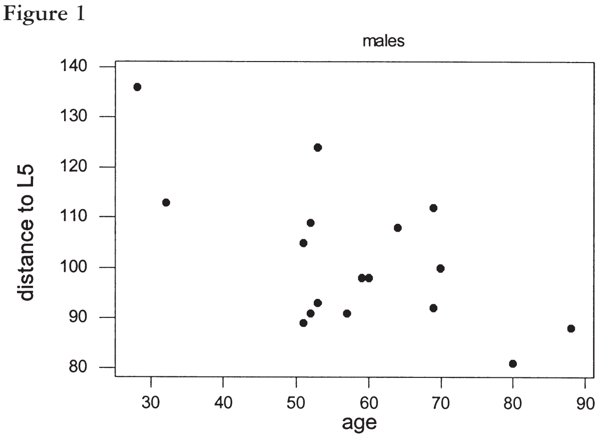
MR imaging procedures

All MR examinations were performed on a Siemens Symphony 1.5-Tessla MR unit (Magnetom Symphony; Siemens, Erlangen, Germany), equipped with Syngo software version VA12B, using a phased array spinal coil. The images used for measurement were Turbo Spin Echo sequences, either T1 or T2 weighting, with fields of view and slice thickness varying from 260 mm to 400 mm and 4 mm to 7 mm respectively. All scans were performed in a supine position.

Image analysis procedures

Sagittal views of the pelvis were retrieved and reviewed at a workstation. The images were enlarged to the maximum possible magnification factor and viewed in the largest format available on the monitor to enable more accurate measurements. Using the graphic tool, which acquires the distance between two specified points, two investigators (MAD and MS) agreed on the location of the SH and then measured the distances to the inferior borders of all visible LSP's as is demonstrated in Fig. 2.

Figure 1



Correlations: C3, C7
Pearson correlation of C3 and C7 = -0.630
P-Value = 0.007

Fig. 1. Distance from the sacral hiatus (SH) to the fifth lumbar spinous process in males in the MRI study. A significant negative correlation is seen. Pearson correlation of C3 and C7 = -0.630. p = 0.007.

Fig. 2. Sagittal section of a pelvic magnetic resonance scan. The distance from the sacral hiatus to the fourth lumbar spinous process is measured at 10.3 cm.

Results

Measurement of the distances from the SH to the inferior border of the fifth, fourth and third LSP was possible in 69, 54, and 11 scans respectively. Forty-eight scans were on females and twenty one were on males. A summary of these measures shown in Table 1 is as follows, with mean distances followed by standard deviation in brackets: The distances in males and females from the SH to fifth LSP were 83.0 (13.7) mm and 71.0 (12.7) mm respectively. The distances in males and females from the sacral hiatus to the fourth LSP were 101.6 (14.2) mm and 92.2 (11.6) mm respectively. The Anderson-Darling Normality test was used to check whether or not the data could be described using the normal distribution. A p value greater than 0.05 was taken as indicating that the finding that distances were normally distributed had not occurred by chance. The p values for the The Anderson-Darling Normality test for L_5 male, L_5 female, L_4 male and L_4 female distances were respectively 0.723, 0.102, 0.264 and 0.053. Accordingly, the data do not contradict the hypothesis that they arise from a normally distributed population in any of these cases. The measurements to the L_3 spine were not analysed in view of the fact that only 11 distances were obtainable. For males (n =2) this was 130 mm (SD not applicable) and for females (n=9) 115.3 (15.3) mm.

A significant negative correlation coefficient (r = - 0.63, p = 0.007) between age and distance from the SH to the fifth LSP was found in males. The technical error of measurement for the technique was found to be 0.23, calculated according to the equation by Ulijaszeck and Mascie-Taylor (1982) on twenty measurements taken by two investigators.

Discussion

Limitations of the study include a bias towards pelvic pathology in subjects and the limited number of measurements to the 3rd LSP. The most common clinical indication for pelvic MR in this hospital is the imaging of a pelvic mass. As this is seen more frequently in women, most of the subjects in this study were female. One possible source of variation other than inter-individual variation is caused by the sacral hiatus being formed by the posterior arch of the 3rd sacral vertebra as opposed to the 4th sacral arch (Soames, 1999). However, this is rare. One source of error in the method employed is measuring the distance to the LSP which is not a discrete point but more of a bony mass of variable size and shape. In this study the distance was measured to a point that was considered most likely to be detected clinically as the most inferior palpable part of the LSP located on a patient's spine prior to performing a spinal injection.

Table 1. Summary of radiological measurements. Distances (mm) from the sacral hiatus (SH) to the lumbar spinous processes as measured on magnetic resonance scans. Means, standard deviations, medians and interquartile ranges are given. p-values derived from Anderson Darling Normality test.

	age (range)	mean (mm)	standard deviation (mm)	p value	Median (mm)	interquartile range (mm)
SH-L_4 (male) n = 17	58.1 (22 - 88)	101.6	14.2	0.264	98	91 - 109
SH-L_5 (male) n = 21	58.4 (22 - 88)	83	13.7	0.723	81	72 - 90
SH-L_4 (female) n = 34	53.2 (32 - 83)	92.2	11.6	0.053	92.5	84 - 102.5
SH-L_5 (female) n = 48	52.5 (20 - 83)	71	12.7	0.102	73.5	61 - 80

Although the Anderson Darling Normality test can be applied to small samples, its power decreases with diminishing sample size. A unique feature of the test is that a p value *exceeding* (>) 0.05 implies a normal distribution.

We could not use lumbosacral MR scans in this study since imaging in these scans did not extend as far as the sacral hiatus. We did not exclude scans showing degenerative disc disease due to the high incidence of this in the population, as described by Jensen et al. (1994). No transitional vertebrae were found in the MR study population. This MR study has demonstrated that the distance from the SH to the 4th and 5th LSP's are normally distributed when measured with this MR technique. An inverse relationship between age and distance from the SH to the fifth LSP in males was also found in the MR study. Based on this, further larger MR studies are planned in order to generate more powerful data and to determine the relationship of these distances (including the SH to the 3rd LSP) with height and age. In this way we hope to be able to develop formulae describing distances from the SH within which neuraxial injection should not incur the risk of direct spinal cord injury. If we can develop this technique and if it were used in conjunction with the use of Tuffier's line then clinicians may have access to two independent techniques to minimise the risk of neurological injury. Large scale cadaveric studies are unlikely to be possible due to the low availability of specimens. In patients with previous spinal surgery, specifically those with posterior fusions and posterior metal rod insertions it may be possible to assist clinicians to avoid the level of surgery when performing spinal/epidural injections as this is less likely to be successful and carries a risk of introducing infection to metal implants. In conclusion, we have found that distances from the SH to the L4 and L5 LSP's are normally distributed when measured with MR scanning. This might lead to the development of a new technique to make LP safer and reassure clinicians.

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References

Aitkenhead AR, Smith G (1996). Local anaesthetic techniques. In: Aitkenhead AR, Smith G (eds). *Textbook of Anaesthesia*. 3rd ed. Churchill Livingstone, London, pp 454.

Auroy Y, Narchi P, Messiah A, Litt L, Rouvier B, Samii K (1997). Serious complications related to regional anaesthesia: results of a prospective survey in France. *Anesthesiology*, 87: 479-486.

Bills DC, Blumbergs P, North JB (1991). Iatrogenic spinal subdural haematoma. *Aust N Z J Surg*, 61: 703-706.

Broadbent CR, Maxwell WB, Ferrie R, Wilson DJ, Gawne-Cain M, Russell R (2000). Ability of anaesthetists to identify a marked lumbar interspace. *Anaesthesia*, 55: 1122-1126.

Jensen MC, Brant-Zawadzki MN, Obuchowski N, Modic MT, Malkasian D, Ross JS (1994). Magnetic resonance imaging of the lumbar spine in people without back pain. *N Engl J Med*, 331: 69-73.

Macdonald A, Chatrath P, Spector T, Ellis H (1999). Level of termination of the spinal cord and the dural sac: a magnetic resonance study. *Clin Anat*, 12: 149-152.

Reynolds F (2000). Logic in the safe practice of spinal anaesthesia. *Anaesthesia*, 55: 1045-1046.

Reynolds F (2001). Damage to the conus medullaris following spinal anaesthesia. *Anaesthesia*, 56: 238-247.

Saifuddin A, Burnett SJD, White J (1998). The variation of position of the conus medullaris in an adult population. *Spine*, 23: 1452-1456.

Soames RW (section Ed) (1999). Skeletal System. Gray's Anatomy. 38th ed. Churchill Livingstone, London, pp 528-531.

Takase K, Sawamura Y, Igarashi K, Chiba Y, Haga K, Saito H, Takahashi S (2002). Demonstration of the artery of Adamkiewicz at multi-detector row helical CT. *Radiology*, 223: 39-45.

Ulijaszeck SJ, Mascie-Taylor CGN (1982). Intra- and inter-observer error in anthropometric measurement. In: Ulijaszeck SJ and Mascie-Taylor CGN (eds). *Anthropometry: the individual and the population*. 3rd ed. Cambridge University Press, Cambridge, pp 30-55.