Surg Radiol Anat (1996) 18 : 133-135

Surgical and Radiologic Anatomy
Journal of Clinical Anatomy

Spinal cord diameters in cadaveric specimens and magnetic resonance scans, to assess embalming artefacts

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Summary: It would be valuable to use cadaveric models of cervical vertebrae and spinal cord to assess how varying degrees of traumatic subluxation would relate to neurological damage. However, before such a study may be undertaken, it would be important to assess the degree of shrinkage or expansion of the spinal cord that occurs during the embalming process. This is achieved in this study by comparing diameters of cadaveric spinal cord to that of sagittal magnetic resonance scans of living subjects. The geometric measurements of radiographs in living subjects has been assessed but no direct model for spinal cord injury has been described [1].

If embalmed spinal cord diameters were a good estimator of living spinal cord diameters then cadaveric cervical spines could be used as a model. By reproducing various degrees of fracture and dislocation the extent of corresponding cord compression could be assessed. Our study shows that spinal cord dimensions increase after embalming using the Cambridge procedure [4].

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Etude des diamètres de la moëlle épinière sur le cadavre et en résonnance magnétique nucléaire, destinée à évaluer les artefacts liés à l'embaumement

Résumé : Il y aurait un grand intérêt à utiliser des vertèbres cervicales et des moelles épinières issues de cadavres pour évaluer quels degrés de subluxation traumatique et quelles lésions nerveuses sont liés. Cependant, avant d'entreprendre une telle étude, il serait important d'appréhender le degré de rétrécissement ou d'élargissement de la moelle épinière qui survient au cours de l'embaumement. C'est ce que nous avons réalisé dans ce travail en comparant les diamètres de la moelle épinière de cadavres à ceux de coupes sagittales obtenues par résonance magnétique nucléaire sur des sujets vivants. Les mesures géométriques sur des radiographies de sujets vivants ont déjà été évaluées, mais aucun modèle directement applicable aux traumatismes de la moelle épinière n'a été décrit [1]. Si les diamètres des moelles épinières embaumées représentaient fidèlement les diamètres des moelles épinières des sujets vivants, les colonnes cervicales de cadavres pourraient être utilisées comme modèles. On pourrait évaluer l'importance de la compression de la moelle épinière correspondant à des degrés variés de fractures et de luxations. Notre étude montre que les dimensions de moelles épinières augmentent après l'embaumement selon la technique de Cambridge [4].

Key words: Spinal cord — Magnetic resonance imaging — Cadaver — Embalming — Anatomy

Methods

The dimensions of the spinal cord and the anteroposterior diameter of the atlas vertebra were measured at levels corresponding to the upper and lower borders of the atlas. Forty two magnetic resonance (MR) scans of male and female patients, aged above seventy five years, were measured (Fig. 1).

GE Sigma Advantage 1.5 T and 1.0 T MR scanners were used, operated by GE Medical Systems Advantage Windows 1.2 software. Sagittal T1 and T2 images were created, displayed on a 24 cm field of view. A repetition time (TR) of 600 ms and an echo time (TE) of 25 ms were used, with an imaging matrix of 512 by 256 elements. The CSF-spinal interface was identified visually, and measurements were made appropriately using the software package. All measurements were made along the lines joi-

Fig. 1
Midline sagittal magnetic resonance images, showing the dimensions which were measured. *E*, epiglottis; *V*, vertebral body; *S*, spinal cord; *tailed arrows*, limits of measurements of the upper and lower diameters of the atlas, from anterior arch to posterior arch; *arrowheads*, limits of the measurements of the spinal cord at the upper and lower levels of the atlas, measured along lines joining the upper borders of the anterior and posterior arches, and the lower borders

Coupe IRM sagittale médiane montrant les dimensions mesurées. *E*, épiglotte ; *V*, corps vertébral ; *S*, moelle épinière ; *flèches complètes*, limites des mesures des diamètres supérieur et inférieur de l'atlas, de l'arc antérieur à l'arc postérieur ; *têtes de flèche*, limites des mesures de la moelle épinière aux niveaux supérieur et inférieur de l'atlas, mesurées le long des lignes unissant les bords supérieurs et les bords inférieurs des arcs antérieur et postérieur

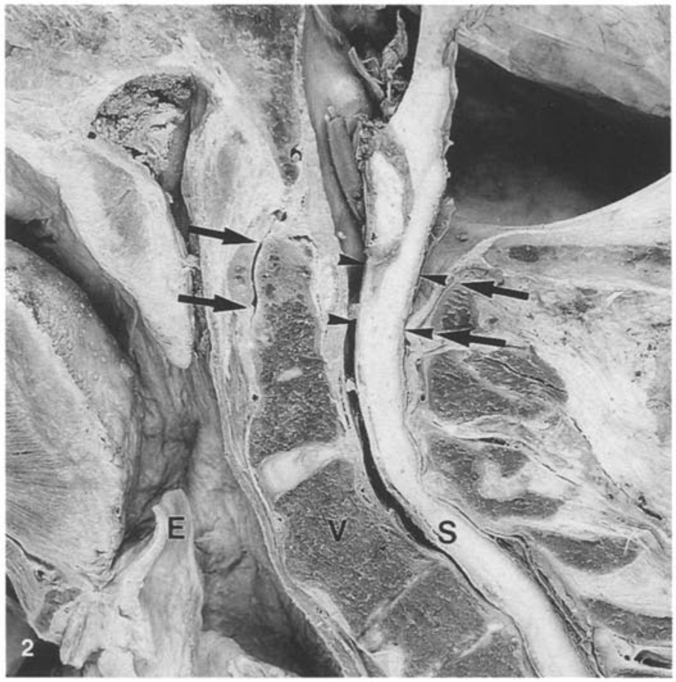

Fig. 2
Midline sagittal section of cadaveric head and neck. *E*, epiglottis; *V*, vertebral body; *S*, spinal cord; *tailed arrows*, limits of the diameters of the atlas as Fig. 1; *arrowheads*, limits of the spinal cord diameters

Coupe sagittale médiane de la région cervico-céphalique d'un cadavre. *E*, épiglotte ; *V*, corps vertébral ; *S*, moelle épinière ; *flèches complètes*, limites des diamètres de l'atlas (voir fig. 1) ; *têtes de flèches*, limites des diamètres de la moelle épinière

ning the upper borders of the anterior and posterior arches of the atlas and the lower borders. The same measurements were made in thirty four cadavers, preserved using a solution consisting of 55% methylated spirit, 12% glycerine, 10% phenol, 3% formaldehyde, as described by the Cambridge procedure, of the Department of Anatomy, University of Cambridge, England [4]. The preserved cadavers were left in storage for a variable period of 4 months to two years, with an approximate mean of 1 year storage. The heads and necks of the cadavers were bisected, allowing measurements to be made in the median sagittal plane, using a vernier gauge. A band-saw was used to bisect the heads, the midline being marked by visual assessment. The measurements of the cadavers were compared to those of the MR scans, used as a control representing living tissues (Fig. 2).

Results

In the MR scans, the diameters measured from the posterior aspect of the anterior arch to the anterior aspect of the posterior arch, at the upper border of the atlas had a mean of 32.4 mm (standard deviation, SD of 2.8 mm), whereas at the lower border the mean was 31.8 mm (SD of 2.9 mm). The 95% confidence intervals were calculated as 27.0-37.8 mm and 25.9-37.7 mm for the upper and lower borders respectively.

The cadaveric means were calculated as 35.1 mm and 34.2 mm at the upper and lower levels; these values fall within the confidence intervals, and suggest that the cadaveric diameters and the MR scan diameters are likely to arise from the same population.

The diameters of the spinal cord from MR scans had means of 7.6 mm (SD of 1.1 mm) and 7.5 mm (SD of 1.2 mm) at the upper and lower levels of the atlas vertebra respectively. The 95% confidence intervals were calculated as 5.4-9.8 mm and 5.2-9.7 mm.

The cadaveric diameters of spinal cord after embalming had means of 10.3 mm and 9.9 mm, falling outside the 95% confidence intervals.

Discussion

The diameter of the spinal cord appears to increase after preservation of the cadaver by the Cambridge procedure ($p = 0.05$).

The error in measurement of the cadaveric dimensions is 0.05 mm. There is also an error in the accuracy of the section of the cadaveric heads, but this is likely to be similar to that of the midline sagittal MR scans, and would be included in the values for the standard deviations for the observations.

In this study, linear measurements were used to represent volume changes of spinal cord. This is considered appropriate since, in cervical injury, it is usually the anteroposterior diameter which is compromised. In our study, MR imaging was used as a control to represent dimensions of living tissues. MR images may be used as unbiased estimators for living cerebrospinal fluid and brain volumes and it was therefore felt justifiable to use linear MR dimensions to represent true measurements of living nervous tissue [2]. One study revealed that there was neurological involvement in 39% of cervical spine fractures [6]. However, fractures in the C1-C2 complex have a lower incidence of spinal cord damage compared to other cervical spine injuries [3]. The mechanism of injury and type of fracture have been shown to correspond with the degree of neurological deficit, but no biomechanical data has been examined. Roaf described the effects of varying forces on vertebrae in postmortem specimens, but did not study the effects on the spinal cord [7]. Comparison of MR imaging of the lumbar spine with cadaveric specimens has been studied [5]. However this was a qualitative study and did not assess the preserving artefact in cadaveric material. The use of cadaveric cervical vertebrae and cord models could be used to provide such biomechanical data, relating the degree of flexion-extension, fracture or subluxation, to the extent of cord injury.

Conclusion

Preserved cadavers may be used to assess the degree of spinal cord impingement with extreme ranges of movements in experimental fractures or dislocations of the cervical spine. However it should be remembered that the living cord volume is less than the preserved cord volume in any such studies.

Acknowledgements. Many thanks to Bari Logan and the staff of the dissecting room, Department of Anatomy, and also Dr. Freer, Department of Radiology, Addenbrookes Hospital.

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Received July 18, 1995 / Accepted in final form February 15, 1996