COMPARATIVE INTERVERTEBRAL DISC ANATOMY ACROSS SEVERAL ANIMAL SPECIES

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Introduction: Animal models are widely used to study intervertebral disc degeneration because of the availability of the tissue, the decreased variability between subjects compared to human tissue, and the feasibility to perform an *in vivo* experiment. Knowledge of the animal disc anatomy compared to that of the human disc is important in order to interpret model results. Little comparative data is available for the disc anatomy of animal models used to study disc degeneration. The objective of this study was to measure geometric parameters of the intervertebral disc and to compare normalized measurements from several animal species with the non-degenerate human disc.

Methods: The lumbar and/or caudal disc geometry of six species was evaluated: baboon (L4-L5, n=2), sheep (L4-L5, n=3), bovine (C2-C3, n=2), rabbit (L4-L5, n=3), rat (L4-L5 and C10-C11, n=3) and mouse (L3-L4 and C9-C10, n=3) and compared to non-degenerate human discs (L4-L5, n=3). Selection of lumbar and/or caudal levels was based on their use in experimental models of disc degeneration. With the exception of the bovine discs, all animals were skeletally mature adults. A lateral radiograph was acquired, and the disc was then cut to obtain an axial section at the center of the disc. Axial sections were imaged using a high resolution CCD camera.

A custom-written MATLAB program was used to make geometric measurements from axial images and lateral radiographs. Measurements were made by selecting the boundary at the disc edge and the boundary between the nucleus pulposus (NP) and the annulus fibrosus. From this input, the cross-sectional area of the whole disc and the nucleus, and the centroid of the two regions were calculated (Fig 1). Once the centroids were determined for the disc and NP, the lateral and anteroposterior (AP) widths were calculated as a line going through the centroid to the disc or nucleus edge, respectively. From the lateral radiographs, the boundary of disc space area was selected and AP width was measured at the middle of the anterior and posterior height. The average disc height was calculated by dividing the total disc space area by the AP width.

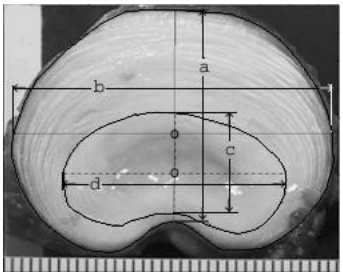

Figure 1: Disc image with the measured dimensions labeled. The disc and NP centroids are labeled 'o' and the calculated dimensions are: (a & c) AP width; (b & d) lateral width of the entire disc and NP, respectively.

Results & Discussion: Several anatomical dimensions were measured, due to space limitations, only measured area and height are presented in the Table. Disc aspect ratio was calculated as the ratio of the lateral width to the AP width. The disc aspect ratio of the baboon and the mouse lumbar are the closest to the human intervertebral disc (Fig 2A). The rat and sheep lumbar disc aspect ratio are 11% and 14% smaller, respectively, than the human disc. The rabbit disc aspect ratio is 30% larger than the human disc. The three caudal discs have a disc aspect ratio approaching 1.0 that of a circle. The anatomy of these tail disc obviously reflect the difference in function of the caudal verses that of the lumbar spine.

The NP area ratio was calculated as the ratio of NP area to the area of the entire disc. The NP area ratio for the baboon and mouse caudal disc is closest to the human discs (Fig 2B). The sheep, bovine caudal, rabbit, and rat lumbar disc have similar NP to disc area ratios, ranging ±20% of the human. The rat caudal disc has the largest size of NP, and is 30% larger than the human NP to disc area ratio. An advantage of having a larger relative NP area is that it may provide better resistance to compressive forces.

The disc height for each disc type was first normalized by dividing by the effective radius, r_e, for that disc type, where r_e = sqrt(Disc area/π). The normalized disc height of the rat and mouse lumbar is most similar to the human (Fig 2C). The largest normalized disc height is the bovine caudal, which is 50% larger than the human disc. The disc height contributes to spine flexibility and energy absorption.

Species	Disc Area (mm^2)	Disc height (mm)
Human	1727 (549)	8.93 (0.13)
Baboon	754 (116)	3.66 (0.07)
Sheep	344 (73)	2.61 (0.59)
Bovine-C	609 (75)	7.98 (0.35)
Rabbit	73.4 (6.1)	1.42 (0.39)
Rat-L	20.4 (2.1)	0.93 (0.24)
Rat-C	8.86 (3.54)	0.94 (0.09)
Mouse-L	1.81 (0.14)	0.31 (0.03)
Mouse-C	1.19 (0.51)	0.24 (0.06)

Table: Average disc area and height (Std. Dev.)

Conclusions: This study evaluated disc anatomy in several species that are used as animal models of disc degeneration. Based on the normalized geometric measurements of the aspect ratio, NP to disc area ratio, and normalized height, the baboon and the mouse lumbar disc are the closest representations of the human anatomy. The sheep, rabbit and rat lumbar discs are moderately close representations of the human, and the bovine, rat and mouse caudal discs were the poorest representation. Choosing an appropriate animal model depends on the question being asked and several factors including, disc geometry, cellularity, biochemistry, and biomechanics. These factors should be considered when choosing the appropriate animal model for intervertebral disc research.

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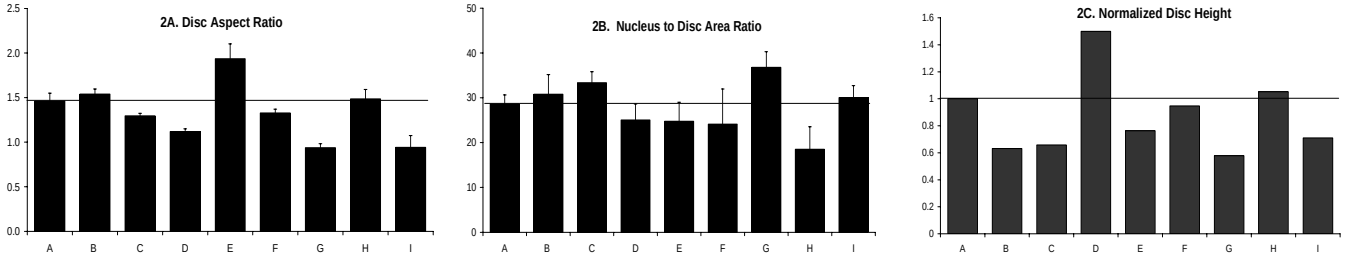

Figure 2A-C: Normalized geometric parameters: (A) human, (B) baboon, (C) sheep, (D) bovine caudal, (E) rabbit, (F) rat lumbar, (G) rat caudal, (H) mouse lumbar, and (I) mouse caudal