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经皮椎体成形术对骨质疏松性胸腰椎骨折患者生物力学的影响研究

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摘要 目的：探讨经皮椎体成形术对骨质疏松性胸腰椎骨折患者生物力学的影响。**方法**：选取 9 具冻存新鲜尸体的胸腰段脊柱开展研究，并应用随机数字表法分为观察组、对照 1 组和对照 2 组，每组各 3 具。观察组、对照 1 组均制作成骨质疏松性胸腰椎骨折模型，观察组经椎弓根注入含有对比剂的低粘度骨水泥，对照 1 组置入椎弓根螺钉内固定，分别于术前和术后测量两组椎体的主要生物力学指标（最大抗压强度、刚度、高度），对照 2 组则作为参照，仅测量一次，对三组生物力学指标检测结果进行统计分析。**结果**：观察组椎体术前的最大抗压强度、刚度、高度与对照 1 组比较差异无统计学意义（P>0.05），但两组术前最大抗压强度、刚度较对照 2 组降低，而高度较对照 2 组升高（P<0.05）。观察组和对照 2 组术后的最大抗压强度、刚度均较对照 1 组升高，高度较对照 1 组降低（P<0.05），而观察组术后的最大抗压强度、刚度、高度与对照 2 组比较差异无统计学意义（P>0.05）。**结论**：应用经皮椎体成形术对骨质疏松性腰椎骨折患者实施治疗，能够有效恢复患者椎体生物力学，效果确切。

关键词：骨质疏松；胸腰椎骨折；经皮椎体成形术；生物力学；影响

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Effects of Percutaneous Vertebroplasty on Biomechanics of Patients with Osteoporotic Thoracolumbar Fractures

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ABSTRACT Objective: To investigate the effects of percutaneous vertebroplasty on the biomechanics of patients with osteoporotic thoracolumbar fractures. **Methods:** A total of 9 frozen fresh cadavers of the thoracolumbar spine were selected for this research and randomly divided into observation group (n=3), control group 1 (n=3) and control group 2 (n=3). The observation group and the control group 1 were made into osteoporotic thoracolumbar fracture models; the observation group was injected with low viscosity bone cement with contrast medium, and the control group 1 was treated with pedicle screw fixation; the main biomechanical indexes (maximum compressive strength, stiffness and height) of the two groups were measured before and after operation. The control group 2 was taken as a reference only, measured only once. The detection results of biomechanical indexes of the three groups were statistically analyzed. **Results:** There were no significant differences in the maximum compressive strength, stiffness and height before operation between the observation group and the control group 1 (P>0.05). However, the maximum compressive strength and stiffness of the two groups were lower than those of the control group 2, and the height was higher than that of the control group 2 (P<0.05). After operation, the maximal compressive strength and stiffness of the observation group and the control group 2 were higher than those of the control group 1, and the height was lower than that of the control group 1 (P<0.05), while there were no significant differences in the maximum compressive strength, stiffness and height after operation between the observation group and the control group 2 (P>0.05). **Conclusion:** The application of percutaneous vertebroplasty in the treatment of osteoporotic vertebral fractures can effectively restore the biomechanical properties of patients, and the effects are exact.

Key words: Osteoporosis; Thoracolumbar fractures; Percutaneous vertebroplasty; Biomechanics; Effects

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前言

胸腰椎骨折为我国临床最为常见的一种技术损伤，各年龄段均可发病，青壮年患者多由交通事故、工伤等高能量损伤所致，老年患者则多为骨质疏松性胸腰椎骨折[1-3]。步入新世纪以来，我国人口老龄化进程不断加快，骨质疏松性胸腰椎骨折患者的发病数量呈现出逐年增长的趋势，不仅严重影响患者生活质量，也给我国社会带来了一定程度的经济负担[4]。我国临床对于骨折后无神经损伤、后凸角度小于 20° 、椎管侵占小于 30%、椎体压缩低于 50%的胸腰椎骨折患者建议接受保守治

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疗，不符合上述条件的胸腰椎骨折患者均需接受手术治疗[5,6]。椎弓根螺钉内固定是我国临床治疗脊椎骨折、畸形的传统手术方式,疗效确切[7]。伴随着外科手术技术的不断进步,经皮椎体成形术问世,为胸腰椎骨折的临床治疗提供了新的方向,但关于该种手术方式对患者骨折椎体生物力学的影响尚无系统性的研究,对于该种手术方式的疗效也尚存在一些争议[8,9]。针对上述现状,本研究以新鲜尸体为研究标本,分析经皮椎体成形术对骨质疏松性胸腰椎骨折患者生物力学的影响,现将研究过程及结果进行以下整理报道。

1 资料与方法

1.1 一般资料

本研究使用 9 具冻存的新鲜尸体开展研究,胸腰段取区域骨密度 0.7~1.0 g/cm^2,均判定为轻度骨质疏松。应用随机数字表法将 9 具尸体分为观察组、对照 1 组、对照 2 组,每组各 3 具尸体，均为 2 具男尸,1 具女尸，观察组年龄 59~72 岁，平均（60.5± 4.7）岁，体重 52~76kg，平均（63.6± 4.5)kg，身高 160~175 cm,平均(167.2± 3.1)cm。对照 1 组年龄 58~75 岁,平均(60.9± 4.2)岁,体重 56~71kg,平均(64.6± 4.5)kg,身高 158~173 cm,平均(166.9± 2.8)cm。对照 2 组年龄 55~73 岁,平均(60.4± 4.4)岁,体重 49~75 kg,平均(65.2± 3.5)kg,身高 164~173 cm,平均(169.5± 3.1)cm。三组尸体在性别比例、年龄、体重、身高上存在的差异均无统计学意义(P>0.05),具有可比性。本研究在医院伦理委员会批准的前提下开展。

1.2 研究方法

1.2.1 标本处理 取三组尸体胸腰椎椎体作为研究标本,节段为 T_{12}~L_2,包括三个椎体和两个椎间盘,并保留附件和相关韧带。将标本放置在室温下自然冻融,浇灌医院骨水泥保证脊柱上下两端水平,对椎体进行编号,在术前应用电子数字显示卡尺（购自深圳市汉普检测仪器有限公司）测量椎体的前径、后径、前侧高度、后侧高度、左侧高度、右侧高度,测量结果精确到 0.01 mm。

1.2.2 骨质疏松性胸腰椎骨折模型建立 取观察组、对照 1 组尸体胸腰段椎体建立骨质疏松性胸腰椎骨折模型,具体制备方法为:将观察组、对照 1 组椎体逐一置于万能材料试验机(购自济南中路昌试验机制造有限公司）的夹板中固定上下两端,滚珠加载,压力感受器最大值设置为 100 kN,位移应用光栅数显高精度测微仪（购自温州三和量具仪器有限公司），精确到 0.1%,使用千分表辅助,加载速度设置为每分钟 5 mm。建模前先在椎体上打孔,以便建模时造成骨折。确定椎体中心后在前屈方向进行滚珠加载,使椎体中部发生楔形塌陷,形成骨折。

1.2.3 实验方法 观察组椎体进行经皮椎体成形术实验方法,具体实验方法为:根据 X 线检查结果确定穿刺点,使用 11G 骨髓穿刺活检针经一侧椎弓根进行穿刺，穿刺针保持向内斜行 15° 进入椎体中前三分之一交界处。在低粘度骨水泥(40 g)中加入 8 g 高纯度(纯度为 99.999%)硫酸钡粉,充分混匀后再于骨水泥中加入单体聚合液,将骨水泥混匀至稍稀糊状,使用 6 mL 注射器抽取 2.5 mL 骨水泥,在影像学工具的引导下将骨水泥加压注射至椎体的骨折孔隙中。对侧椎体也以相同的方法注射骨水泥,使每个椎体内注射的骨水泥均为 5.0 mL,注射结束后 1 小时进行生物力学相关指标测试。

对照 1 组椎体进行椎弓根螺钉内固定实验,具体实验方法为：椎弓根内固定螺钉长度 45 mm，直径为 5.5 mm，螺距 2 mm,实验中置入深度以螺钉长度为上限。在对照 1 组椎体相临的上下椎体两侧椎弓根共置入 4 枚内固定螺钉,术中避免内固定螺钉穿破椎弓根,按常规椎弓根固定方式进行固定,将内固定螺钉的内固定棒分别固定于螺钉尾部，椎体高度与术前相同。对照 2 组为空白参照。

1.2.4 生物力学指标测量 本研究选取椎体主要生物力学指标,具体包括最大抗压强度、刚度、高度。最大抗压强度测量方法：将每个测试椎体放入两钢板之间进行生物力学指标测量,将加载位点设置在椎体前方皮质后侧 5 mm 处,调整好位置后以每分钟 5 mm 的加载速率进行轴向压缩,系统自动采集位移数据和显示载荷 - 位移曲线,该曲线上的第一个峰值即为椎体的最大抗压强度。

刚度测量方法:载荷 - 位移曲线上 448N~1112N 之间的直线部分的斜率作为椎体的刚度。高度:各椎体压缩后的高度平均值即为高度。

1.3 观察指标

对比三组椎体建模后(术前)、实验后(术后)的最大抗压强度、刚度以及高度。

1.4 数据分析处理

本研究基于统计学软件(版本 SPSS22.0)建立数据分析模型,计数资料以率(%)的形式描述,指标间差异采用卡方(x^2)检验,计量资料以均数± 标准差($\bar{x}\pm s$)的形式描述,指标间差异采用独立样本(t)检验,多组计量资料比较采用 F 检验,P 值小于 0.05 表示两者之间存在的差异具有统计学意义。

2 结果

2.1 三组术前最大抗压强度、刚度、高度比较

三组椎体的术前生物力学指标整体比较发现,最大抗压强度、刚度无统计学差异(P>0.05),高度有统计学差异(P<0.05);观察组椎体术前的最大抗压强度、刚度、高度与对照 1 组比较差异无统计学意义(P>0.05),但两组术前最大抗压强度、刚度均低于对照 2 组,而高度高于对照 2 组,差异具有统计学意义(P<0.05),具体数据见表 1 所示。

2.2 三组术后最大抗压强度、刚度、高度比较

三组术后最大抗压强度、刚度、高度整体比较有统计学差异(P<0.05),观察组和对照 2 组术后的最大抗压强度、刚度均高于对照 1 组,高度低于对照 1 组,差异均有统计学意义(P<0.05),而观察组术后的最大抗压强度、刚度、高度与对照 2 组比较差异无统计学意义(P>0.05),具体研究数据见表 2 所示。

3 讨论

骨质疏松性胸腰椎骨折的发生造成的负面危害较大,及时采取有效方案对患者实施治疗以恢复患者伤椎生物力学是促进患者早日康复的关键[10]。经皮椎体成形术是现阶段我国临床治疗骨质疏松性胸腰椎骨折较常用的一种治疗方式[11]。本研究分析经皮椎体成形术对骨质疏松性胸腰椎骨折患者生物力学的影响,旨在为患者选择手术治疗方案提供参考价值。近年来

表 1 对比三组术前最大抗压强度、刚度、高度($\bar{x}\pm s$)

Table 1 Comparison of maximum compressive strength, stiffness and height before operation among three groups ($\bar{x}\pm s$)

Groups	Maximum compressive strength (N)	Stiffness (N/mm)	Height (mm)
Observation group	1498.3± 421.3*	1013.8± 212.8*	7.6± 0.9*
Control group 1	1493.7± 419.5*	1025.7± 214.6*	7.7± 1.1*
Control group 2	1946.2± 422.7	1102.9± 209.8	0.0
F	0.516	0.713	6.936
P	0.429	0.388	0.000

Note: compared with the control group 2, *P<0.05.

表 2 对比三组术后最大抗压强度、刚度、高度($\bar{x}\pm s$)

Table 2 Comparison of maximum compressive strength, stiffness and height after operation among three groups ($\bar{x}\pm s$)

Groups	Maximum compressive strength (N)	Stiffness (N/mm)	Height (mm)
Observation group	1937.6± 415.4*	1098.7± 205.7*	0.3± 0.1*
Control group 1	1678.1± 421.3	1069.5± 203.2	2.3± 0.3
Control group 2	1946.2± 422.7*	1102.9± 209.8*	0.0*
F	1.462	1.918	2.402
P	0.039	0.025	0.000

Note: compared with the control group 1, *P<0.05.

世界范围的胸腰椎骨折主流生物力学实验研究均认为 25%压缩性骨折模型较易进行比较，若大于该压缩比例，实验过程中容易出现骨水泥渗漏的现象，继而易导致实验结果出现误差[12-14]。故我院本次研究中将骨折模型的压缩比设置为 25%，以确保研究结果的准确性和客观性。

本研究分别以椎弓根螺钉内固定椎体模型和空白标本作为对照，深入分析经皮椎体成形术治疗骨质疏松性胸腰椎骨折对患者椎体生物力学指标的影响。研究过程中发现观察组椎体的压力曲线上升起始较为缓慢，出现这一状态的原因主要与椎体脊柱功能单位中两个椎间盘和发生骨质疏松椎体的蠕变等因素有关，随着位移的变化，蠕变因素也会逐渐被消除，观察组椎体的抗压强度曲线的上升速度也会加快[15,16]。而正常椎体的载荷 - 位移曲线形状类似于字母 "S"，当椎体抗压强度达到一定的峰值后就会出现下降的趋势，经一定的位移后再度回升[17,18]。观察组椎体的载荷 - 位移曲线出现上述变化趋势表明经皮椎体成形术中注入的骨水泥能够填充骨折间隙，使椎体有足够的支撑力。对照 1 组椎体早期的载荷 - 位移曲线上升速度较快，但其最大抗压强度曲线随着椎体高度的降低而降低，位移也逐渐加大，这一变化趋势表明内固定螺钉具有一定的弹性模量和较细螺钉对抗压力的局限性。

本研究以中老年尸体胸腰段椎体作为研究标本，经骨密度检测均符合轻度骨质疏松判定标准，研究样本均衡性较好。本研究总结经皮椎体成形术和椎弓根螺钉内固定的生物力学特点为：(1)经皮椎体成形术：实验过程中在观察组椎体中注入骨水泥发现，骨水泥能够较好的填充骨折椎体的骨折间隙，水泥与骨界面的紧密接触是保证椎体获得基础力学的前提条件[19-21]。(2)椎弓根螺钉内固定：观察发现螺钉置入后的压力作用会对椎体产生一定程度的剪切力，该剪切力的存在会对椎体的稳定性产生影响[22,23]。此外，椎体的抗压强度和刚度仅靠几根内固定螺钉承载压力较大，故生物力学较注入骨水泥差[24]。

本次研究显示观察组、对照 1 组椎体术前的最大抗压强度、刚度、高度比较均不存在明显差异，但与对照 2 组比较均存在明显差异。观察组椎体术后的最大抗压强度、刚度、高度与对照 2 组比较无明显差异，对照 1 组椎体术后的最大抗压强度、刚度、高度与对照 2 组和观察组比较均存在明显差异，提示经皮椎体成形术治疗骨质疏松性胸腰椎骨折，能够促进患者椎体生物力学恢复，分析原因为临床上的胸腰椎骨折多为前屈型损伤，应力集中在椎体的前部，因此通过向椎体偏前部注射骨水泥能够增强椎体的整体抗压强度，改善椎体生物力学性能[25-27]。有研究对比经皮椎体成形术和椎弓根螺钉内固定治疗骨质疏松性胸腰椎骨折对患者椎体生物力学的影响，结果显示经皮椎体成形术组骨水泥分布面积均大于 50%，平均最大抗压强度、刚度均高于椎弓根螺钉内固定组[28-30]。我院上述研究结果与上述实践研究所得结果基本保持一致。

综上所述，本研究认为应用经皮椎体成形术对骨质疏松性腰椎骨折患者实施治疗，能够有效恢复患者椎体生物力学，效果确切。但由于本次研究的椎体样本量较少，研究过程中的相关操作有待规范，因此本次研究所得结果仍需临床进行大量实践研究进行验证，以获得科学、准确、客观的实践研究结果。

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