

论著·临床研究

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剪切波超声弹性成像对冈上肌腱滑囊侧部分撕裂的诊断价值分析*

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[摘要] **目的** 探究剪切波超声弹性成像(SWE)对于冈上肌腱滑囊侧部分撕裂的诊断价值,并比较其与磁共振成像(MRI)及二维超声对冈上肌腱滑囊侧部分撕裂的诊断价值差异。**方法** 选取该院骨科行肩关节镜手术的62例患者为研究对象,根据有无肩袖损伤分为无撕裂组(24例)和部分撕裂组(38例)。术前行肩关节MRI、SWE测定及肩关节超声。定量测定双侧冈上肌腱与肌腹的杨氏模量,与对侧进行比较,受试者工作特征(ROC)曲线分析对冈上肌腱侧部分撕裂的诊断效能。**结果** 与无撕裂组比较,部分撕裂组术侧冈上肌腱SWE值明显升高,且两组术侧冈上肌腱SWE值较对侧升高,差异有统计学意义($P<0.05$)。当术侧较对侧的SWE变化值 δ SWE为20.36 kPa时,诊断部分撕裂的灵敏度为84.2%,特异度为100.0%,高于MRI($P=0.0029$)及二维超声($P=0.0019$)。**结论** SWE测定对冈上肌腱部分撕裂诊断具有应用价值。

[关键词] 冈上肌腱部分撕裂;肩袖损伤;超声;剪切波弹性成像;诊断**[中图法分类号]** R445.1**[文献标识码]** A**[文章编号]** 1671-8348(2022)18-3100-05

Diagnostic value of shear wave elastography for partial tear of supraspinatus tendon bursa*

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[Abstract] **Objective** To explore the diagnostic value of shear wave elastography (SWE) for partial tear of supraspinatus tendon bursa and compare its value with two-dimensional ultrasound and magnetic resonance imaging (MRI) for supraspinatus tendon bursa side partial tear. **Methods** A total of 62 patients who underwent arthroscopic shoulder surgery in the department of orthopedics of this hospital were selected as the research objects. According to whether there was rotator cuff injury or not, they were divided into two groups: the no tear group (24 cases) and the partial tear group (38 cases). MRI, SWE, and ultrasound were performed before the operation. The elasticity modulus of supraspinatus tendon and muscle belly were measured in the affected and contra-lateral normal shoulder. Compared with that of the opposite side, receiver operating characteristic (ROC) curve was used to analyze the diagnostic efficacy of lateral supraspinatus tendon tear. **Results** Compared with the no tear group, the SWE value of the supraspinatus tendon in the partial tear group was significantly increased, and the SWE value of the supraspinatus tendon on the operative side in the two groups was higher than that in the opposite side, the difference was statistically significant ($P<0.05$). When the SWE change value (δ SWE) of the supraspinatus tendon on the operative side was 20.36 kPa higher than that on the opposite side, the diagnostic sensitivity reached 84.2%, with a specificity of 100.0%, which was significantly higher than MRI ($P=0.0029$) and two-dimensional ultrasound ($P=0.0019$). **Conclusion** SWE measurement has application value

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in the diagnosis of supraspinatus tendon tear.

[Key words] supraspinatus tendon partial tear; rotator cuff injure; ultrasound; shear wave elastography; diagnosis

肩袖撕裂是引起肩部疼痛和功能障碍的常见原因,普通人发病率约 20.7%。肩袖撕裂分为全层撕裂和部分撕裂,后者细分为滑囊侧部分撕裂、肌腱内部分撕裂、关节侧部分撕裂 3 种。超声具有和磁共振成像(magnetic resonance imaging, MRI)相近的肩袖撕裂诊断价值,但较小的、慢性部分撕裂常与肌腱病影像无法准确分别。剪切波超声弹性成像(shear wave elastography, SWE)是通过测定剪切波在组织内传播速度来定量计算组织弹性的超声波技术,在肌腱损伤疾病中有广泛应用^[1-4],但其对于冈上肌腱滑囊侧部分撕裂的应用价值目前尚无报道。因此,本研究将利用 SWE 技术定量测定冈上肌腱与肌腹的杨氏模量,探究改变值对于冈上肌腱滑囊侧部分撕裂的诊断价值,并比较 SWE 技术与常规肌骨超声、MRI 对冈上肌腱滑囊侧部分撕裂的诊断价值差异,现报道如下。

1 资料与方法

1.1 一般资料

选取 2020 年 6 月至 2021 年 8 月本院骨科行肩关节镜手术的 62 例患者为研究对象。纳入标准:(1)单侧肩关节疼痛,查体符合冈上肌腱撕裂患者;(2)因肩关节脱位、肩锁关节脱位、孟唇损伤行手术患者。排除标准:(1)术中证实为冈上肌腱全层撕裂或单纯下表面撕裂;(2)合并其他肩袖肌群撕裂;(3)术前双侧受累。根据有无肩袖损伤分为无撕裂组(24 例)和部分撕裂组(38 例),无撕裂组术中确证无肩袖损伤,部分撕裂组术中诊断为冈上肌腱滑囊侧部分撕裂,所有患者均为优势手侧肩关节受累,两组一般资料比较,差异无统计学意义($P > 0.05$),具有可比性。本研究获得医院伦理委员会批准(批号:2020-795),所有患者术前均签署知情同意书。

表 1 两组一般资料比较

项目	无撕裂组 (n=24)	部分撕裂组 (n=38)	$t/\chi^2/Z$	P
年龄($\bar{x} \pm s$, 岁)	30.3 ± 8.0	56.7 ± 12.0	-10.350	<0.001
性别[n(%)]			3.119	0.077
男	13(54.2)	12(31.6)		
女	11(45.8)	26(68.4)		
病程[M(Q1, Q3), 月]	5.00(3.00, 7.00)	5.00(3.00, 8.25)	504.500	0.481

1.2 方法

1.2.1 超声检查

使用东芝 aplio 800 超声系统,患者 0°外展,上臂完全放松坐立位进行双侧肩关节扫查,按照超声诊断标准对冈上肌腱撕裂情况进行检查并记录撕裂情况^[5]。SWE 测定:使用超声换能器(L12-5)进行测量,其中肌腱的测量点在冈上肌腱肱骨大结节附着点内侧 1 cm 处,肌腹的测量点位于肩峰后外侧角与肩胛冈根部连线中点上方 2 cm 处。超声探头与肌腱纤维走行方向一致进行取样,手动选择在感兴趣区中测量 SWE 值^[1,3,6]。所有 SWE 值均测量 3 次取平均值进行记录分析。以上超声检查由同一具有 5 年以上肌骨超声工作经验的医师完成。

1.2.2 MRI 检查

患者仰卧,上肢中立位,使用 Siemens 1.5 T MRI 系统进行扫描。扫描定位时,斜冠状面与冈上肌肌腱长轴平行,斜矢状面则与冈上肌肌腱长轴垂直。MRI 扫描序列包括斜冠状位 PD-weighted fat saturation (TR/TE, 2 410/44 ms, FOV 17 cm × 17 cm, 层厚 3.5 mm),斜矢状位及轴位 PD-weighted tirm (TR/TE, 2 890 ~ 3 630/33 ~ 37 ms, FOV 18 cm × 18 cm, 层厚 4.0 mm),以及斜矢状位及斜冠状位 T1-weighted turbo spin echo (TR/TE, 284 ~ 346/12 ~ 13 ms, FOV 18 cm × 18 cm, 层厚 4 mm)。肩袖滑囊侧部分撕裂的诊断标准:在 T2 加权脂肪抑制序列中,肩袖肌腱滑囊侧出现未贯穿全层的异常高信号。

1.2.3 肩关节镜手术流程

肩关节镜手术均由同一位医师完成。术中诊断冈上肌腱滑囊侧部分撕裂标准:关节镜先进入孟肱关节腔内探查,冈上肌腱关节侧未见撕裂表现;随后关节镜进入肩峰下间隙,清理肩峰下间隙后,探查可见冈上肌腱滑囊侧部分撕裂。充分清理质量差的肌腱及炎症物质后使用带线锚钉进行肌腱缝合修复。

1.3 统计学处理

采用 SPSS26.0 及 MedCalc20.011 软件进行数据分析,符合正态分布的计量资料以 $\bar{x} \pm s$ 表示,比较采用 t 检验;不符合正态分布的计量资料以 M(Q1, Q3)表示,比较采用秩和检验;计量资料以频数或百分率表示,比较采用 χ^2 检验;受试者工作特征(ROC)曲线分析诊断效能,以 $P < 0.05$ 为差异有统计学意义。

2 结果

2.1 两组双侧肌腱及肌腹 SWE 值比较

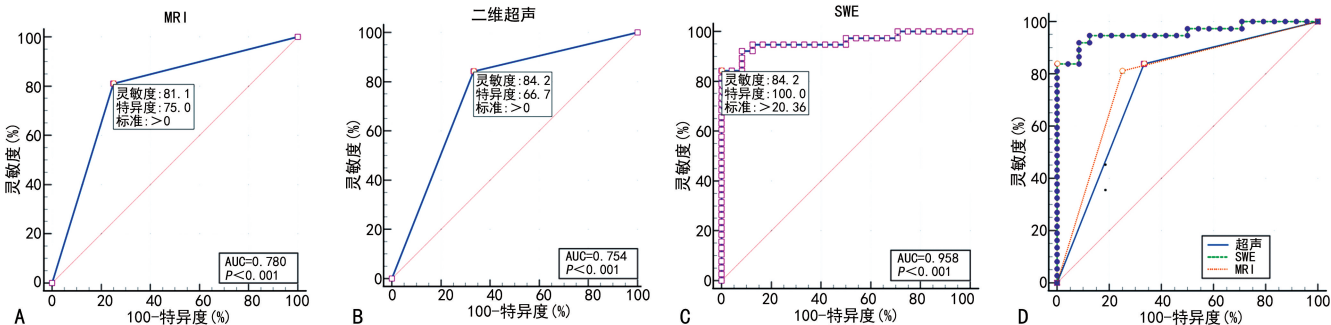
与无撕裂组比较,部分撕裂组术侧冈上肌腱 SWE 值明显升高,且两组术侧冈上肌腱 SWE 值较对侧升高,差异有统计学意义($P < 0.05$),见表 2。

表 2 两组双侧肌腱及肌腹 SWE 值比较($\bar{x} \pm s$, kPa)

项目	无撕裂组 ($n=24$)	部分撕裂组 ($n=38$)	t	P
冈上肌腱				
术侧	117.85 \pm 9.09 ^a	137.95 \pm 11.11 ^a	-7.425	<0.001
对侧	109.74 \pm 7.07	111.25 \pm 9.23	-0.684	0.496
冈上肌腹				
术侧	108.73 \pm 7.32	107.24 \pm 9.23	0.672	0.504
对侧	108.28 \pm 6.23	107.14 \pm 6.21	0.704	0.484

^a: $P < 0.05$, 与对侧比较。

2.2 ROC 曲线分析



A: MRI; B: 二维超声; C: SWE; D: 3 种诊断方式对比。

图 1 不同诊断方式对冈上肌腱部分撕裂诊断的 ROC 曲线

3 讨论

中老年人群中症状性肩袖损伤的发病率随年龄增长而升高,其中以冈上肌腱前 1/3、肱骨大结节上方 1 cm 处血供最少,最易发生撕裂。肩袖部分撕裂发生率明显高于全层撕裂,目前对全层撕裂的关节镜下诊治已相当成熟,但目前对肩袖滑囊侧部分撕裂诊断及治疗策略选择暂无共识。保守治疗作为首选,研究表明,富含血小板血浆较皮质类固醇注射可明显改善短期疼痛缓解和功能,但对远期预后无影响^[7-8]。尽管保守治疗有效,但肩袖部分撕裂总体将以每月 0.26% 的速率进展为全层撕裂,而有症状人群中以高达每月 0.32% 进展为全层撕裂^[9]。因此,对于高级别部分撕裂,手术治疗将取得更好的预后^[10-12]。

研究发现术前肌腱质量是肩袖修复术后愈合能力的独立影响因素^[13],早期固定、修复部分撕裂的肌腱将取得更好的临床疗效^[13-15]。动物实验也证明,将部分撕裂转变为全层撕裂后再修复将提供更好的腱骨愈合和更低的再撕裂率,可能是由于清创去除了质量差的肌腱组织,创造了更好的愈合环境^[16]。因此,

术前 MRI 对冈上肌腱部分撕裂诊断的灵敏度为 81.1%,特异度为 75.0%,曲线下面积(AUC)为 0.780。二维超声对冈上肌腱滑囊侧部分撕裂的诊断灵敏度为 84.2%,特异度为 66.7%,AUC 为 0.754。当以对侧冈上肌腱 SWE 值为参考,计算术侧冈上肌腱较对侧升高的变化值(δ SWE),结果显示 δ SWE 的 AUC 为 0.958,95%CI:0.875~0.993。当 δ SWE > 20.36 kPa 时,其对冈上肌腱滑囊侧部分撕裂的诊断灵敏度为 84.2%,特异度为 100.0%,阳性预测值为 100.0%,阴性预测值为 80.0%。比较这 3 种诊断工具对冈上肌腱滑囊侧部分撕裂的术前诊断价值,结果显示 δ SWE 较术前 MRI($P = 0.0029$)及二维超声($P = 0.0019$)具有更高的诊断效能;MRI 和二维超声诊断效能比较,差异无统计学意义($P = 0.70$),见图 1。

需要提高肌腱滑囊侧部分撕裂的影像诊断检出率,指导临床早期干预,阻止肌腱发展为全层撕裂,或巨大肩袖撕裂。

MRI 对肩袖部分撕裂仅有 67%~83% 的灵敏度^[17],对患有幽闭恐惧症、不能平卧或体内有起搏器、部分金属支架材料的患者不适用,临床应用有一定的局限性。动态扫描特性使得二维超声对肩袖部分撕裂的诊断可达到与 MRI 相近甚至更高的诊断准确性,本课题组既往研究也显示超声对肩胛下肌腱的部分撕裂诊断能力高于 MRI^[18]。近年来有研究将其作为评估肩袖滑囊侧部分撕裂是否需要修复的检查方式^[19-20]。与之相符,本研究结果显示术前 MRI 对冈上肌腱滑囊侧部分撕裂的诊断灵敏度为 81.1%,特异度为 75.0%。常规肌骨二维超声诊断灵敏度为 84.2%,特异度为 66.7%。二者对冈上肌腱滑囊侧部分撕裂的诊断准确性无差异。二维超声在检测部分厚度撕裂方面表现可以达到高于 MRI 的诊断准确性,但对超声操作医师的要求较高,学习曲线较长^[12,21]。尽管如此,二维超声与 MRI 仅能进行肌腱

形态学上的描述,难以提供肌腱力学性能的信息。

当肌腱内纤维断裂后,肌腱胶原结构变性,纤维母细胞分化、脂肪和血管浸润,肌腱收缩和纤维化^[22]。同时,损伤后周围慢性炎性环境,炎性细胞因子、血管内皮生长因子和缺氧诱导因子表达增加,参与肩袖进一步损伤进展及促进纤维化,肌腱硬度增高,生物力学性能下降^[23]。SWE 原理是在组织中产生剪切波,然后通过超声成像获得剪切波的传播速度,即可算出组织的弹性系数(杨氏模量 $E=3\rho c^2$,单位为 kPa,其中 c 为剪切波传播速度, ρ 为组织密度)。测量的杨氏模量越大,说明组织硬度越大^[4]。SWE 可对弹性系数进行多点测量,具有安全、有效、准确且重复性较好等优点^[24]。近几年,SWE 逐渐应用于肩袖、髌腱、跟腱疾病的诊断及预后相关性分析^[25-26]。KREPKIN 等^[27]研究表明冈上肌腱 MRI 的 T2 值与 SWE 值存在相关性。LIN 等^[28]研究显示,SWE 可以检测冈上肌内的生物力学差异,这些差异在灰度超声上并不明显。与较低级别的肌腱异常和全层撕裂相比,伴有中至重度肌腱变性的冈上肌腱部分撕裂的 SWE 值升高明显,提示可能对应于不同的生物力学特性。YOO 等^[29]研究结果显示,持续超过 1 年的慢性肩痛患者冈上肌腱撕裂的 SWE 值明显升高。另一项研究表明,术前的冈上肌腹及冈下肌腹的 SWE 值升高与肩袖撕裂大小及不可修复性呈正相关^[29]。HUANG 等^[30]研究结果也显示术前 SWE 值升高可作为肩袖撕裂患者修复困难的标志物。本研究结果显示在无冈上肌腱撕裂的患者中,双侧冈上肌腹 SWE 值无明显差异,但术侧冈上肌腱 SWE 值明显大于对侧($P<0.05$),这可能与优势侧肩部肌腱更发达相关。在诊断为冈上肌腱滑囊侧部分撕裂的患者人群中,双侧冈上肌腹 SWE 值无差异,但当肌腱滑囊侧部分撕裂后,肌腱内纤维回缩、瘢痕增生修复,术侧冈上肌腱 SWE 值明显高于对侧($P<0.05$)。

由于笔者发现在无撕裂的正常人群中,优势侧肩部肌腱 SWE 较对侧明显升高,若单纯计算人群 SWE 均值或中位数值将对结果准确性造成影响。因此,以对侧肌腱为对照,计算术侧冈上肌腱较对侧升高的幅度 δ SWE。ROC 曲线分析结果显示采取该值对冈上肌腱滑囊侧部分撕裂的患者的诊断 AUC 值高达为 0.958(95%CI:0.875~0.993)。当设定 δ SWE 截断值为 20.36 kPa 时,约登指数取得最大值, δ SWE 对冈上肌腱滑囊侧部分撕裂的灵敏度为 84.2%,特异度达 100.0%,阳性预测值为 100.0%,阴性预测值为 80.0%,高于 MRI 及二维超声的诊断价值($P<0.05$)。

综上所述,SWE 可客观反映肌腱组织硬度,当肌

腱滑囊侧部分撕裂时,患侧 SWE 值较对侧明显升高。定量分析具有高于二维超声及 MRI 的诊断价值,同时操作简便、可重复进行等优点,具有临床应用价值。此外,需要做到以下几点来提高 SWE 的准确性:首先,检查时建议患者采取坐位,双上肢 0°外展、外旋中立位;其次,将前臂放在大腿上,保持肩部放松,以避免冈上肌和冈下肌的肌肉的收缩;最后,检查者在检查时不宜施加较大的力于超声探头上,仅需轻轻地接触皮肤即可,以降低对结果影响。

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