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Original Research

Rate of Unexpected Findings in Adolescent Lumbar Magnetic Resonance Imagings Ordered by Orthopaedic Surgeons

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ABSTRACT

Background: The use of advanced imaging in children is increasing and unexpected findings (UFs) are often detected. The present literature lacks studies investigating the rate of UFs in pediatric lumbar spine magnetic resonance imagings (MRIs) and the sequelae of these findings. This study aimed to determine the overall incidence of UFs in adolescent lumbar MRIs, characterize these findings, stratify UFs based on patient characteristics, and determine any influences on patient treatment plans.

Methods: Medical records of 1409 patients aged 10 to 18.5 years old that had a lumbar MRI ordered by an orthopaedic surgeon from 2010 to 2020 were reviewed retrospectively. Demographics, insurance, reason for MRI, and change in treatment plans were noted. Unexpected findings were characterized as spinal cord, infraperitoneal, retroperitoneal, peritoneal, or vascular-related. The relationship between patient characteristics and UFs was investigated using a *t* test and Chi-square test. The statistical relationships between UFs and treatment plan changes were evaluated using generalized linear models with a log link and a binomial error distribution.

Results: The average age of the 1409 patients was 15.5 years (95% CI: 15.4, 15.6). Back pain (90.1%) was the most common reason for lumbar MRI. Thirty-five UFs were found in 33 patients (2.3%): 19 were spinal cord-related, 15 were peritoneal-related, and one was vascular. Eight peritoneal findings involved the kidneys: two atrophy, two hypoplasia, two renal cysts, one pelvic kidney, and one hydronephrosis. Five patients had a syrinx, and two had spine tumors. Out of 33 patients with UFs, 11 required a change in treatment plan (33.3%). Back pain was not associated with an increased risk of UF. Patients with an UF on MRI had 2.60 times higher odds of experiencing a change in treatment plan.

Conclusions: The prevalence of UFs was 2.5% on lumbar MRIs and were mainly spinal cord or retroperitoneal-related. UFs were associated with an altered treatment plan 33% of the time and were unrelated to standard demographic characteristics or insurance type.

Key Concepts:
(1) Overall, 33.3% of patients with an unexpected finding had a change in treatment plan.
(2) Unexpected findings should be interpreted in the context of the patient's overall clinical picture, symptoms, and health to help elucidate the next steps in treatment.
(3) The clinical significance of unexpected findings needs to be further studied.

Level of Evidence: Level III, Retrospective

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Introduction

Magnetic resonance imaging (MRI) is an advanced, useful imaging technique that can highlight findings within soft tissues due to its high degree of soft-tissue contrast [1–3]. MRI provides a detailed image that often detects findings unrelated to the initial indication for the study. An unexpected finding (UF) on MRI is defined as a pathology "not previously detected or suspected clinically, but identified by an imaging study [4]." These IFs can involve the organ of interest or be unrelated to the organ system.

While there have been a small number of studies investigating the rate of UFs in pediatric MRIs, the current literature lacks an adequate number of studies investigating the rate of UFs in pediatric lumbar spine MRIs. Additionally, there is insufficient investigation of the sequelae of these findings, such as whether these UFs affect the treatment plan, defined as any alteration from the initial plan such as referral to another subspecialty, secondary advanced imaging, or surgery. Previous studies have not reported whether UFs are clinically relevant. Furthermore, the current literature focuses largely on adults and different studies report variable incidence rates of these UFs. For example, Maxwell et al., [5] Tuncel et al. [6], and Quattrochi et al. [7] reported varying rates of UFs when investigating the lumbar area with the same imaging modality of MRI (33.2%, 18.8%, and 68.6%, respectively). Additionally, a study investigating 540 children who received an MRI due to potential juvenile spondylarthritis discovered UFs at twice the rate of sacroiliitis [8]. It is uncertain why such disparity in the rates of UFs, even when limited by the same imaging modality and area of interest, have been reported, but more studies are needed to elucidate the true incidence, as well as their implications.

The purpose of this study was to determine the overall incidence of UFs in pre-adolescent and adolescent lumbar MRIs. This study also aimed to stratify the odds of discovering UFs based on patient characteristics and determine any influences on patient treatment plans. Lastly, it sought to evaluate the clinical significance of UFs, defined as the percentage of patients whose UF directly results in a change in treatment plan. We hypothesized that a significant portion of imaging studies would display unexpected findings that would translate into resultant changes in treatment plans.

Methods

This retrospective study was approved by our center's institutional review board; informed consent of patients was waived. Medical records of patients aged 10 to 18 years old that had a lumbar MRI ordered by an orthopaedic surgeon from 2010 to 2020 were reviewed. Patient demographics, insurance, reason for MRI, and any change in treatment plans were noted. The initial clinic note with a plan of treatment was reviewed. Changes in treatment plan were defined as any action that differed from the original plan of care such as referral to another provider, additional imaging, or an additional procedure, including surgery. Unexpected findings were defined as a pathology "not previously detected or suspected clinically, but identified by an imaging study." [4] They were characterized as spinal cord-related, vascular, infra-peritoneal, retroperitoneal, and peritoneal. Exclusion criteria included patients over 18 years and incomplete data, such as lack of follow-up for patients with UFs.

Statistical analyses

The frequency and percentage of patients' characteristics were reported, and analysis determined if they were associated with the presence of UFs using a *t* test or Chi-square test. The mean prevalence and 95% confidence interval (CI) of incidental MRI findings were reported. The factors influencing the presence of UFs, and whether the presence of incidental MRI findings influenced the treatment plan, were evaluated using generalized linear models with a log link and a binomial error distribution and reported as the risk ratio and 95% CI. Statistical models were adjusted for age, sex, race, presence of government insurance, and presence of back pain and weakness as symptoms.

Results

Demographic variables of patient population

Inclusion criteria were met by 1409 patients. Their average age was 15.5 years; 53.6% were females (n = 755), 67.9% of patients were white, 18.9% were black, and 89.2% had private insurance. Back pain (90.1%) was the most common reason for lumbar MRI. The distribution of patients' characteristics across the presence or absence of unexpected MRI findings is listed in Table 1.

Unexpected findings

There were 35 total unexpected MRI findings from 1409 scans in 33 (2.3%) patients: 19 were spine-related, five were infra-peritoneal, eight were retroperitoneal, two were peritoneal, and one was vascular

Table 1.
Patient characteristics.

Characteristics	Unexpected MRI findings		*P* value for difference
	Yes	No	
Age (mean, 95% CI)	15.39 (14.71, 16.07)	15.54 (15.45, 15.64)	.648
Sex, % (n)			.917
Male	45.45 (15)	46.37 (638)	
Female	54.55 (18)	53.63 (738)	
Race, % (n)			
African American	27.27 (9)	18.68 (257)	.854
White	63.64 (21)	68.02 (936)	
Asian	0 (0)	1.74 (24)	
Hispanic	0 (0)	1.53 (21)	
Mixed	0 (0)	0.44 (6)	
Others/unknown	9.09 (3)	9.45 (130)	
Insurance type, % (n)			
Private	87.88 (29)	89.24 (1228)	.026
Government	12.12 (4)	4.00 (55)	
Others	0 (0)	6.76 (93)	
Reasons for MRI, % (n)			
Back pain	84.85 (28)	90.19 (1241)	<.001
Weakness/ numbness	6.06 (2)	0.29 (4)	
Fracture	0 (0)	1.09 (15)	
Others	0 (0)	3.63 (50)	
Back pain + others	9.09 (3)	3.56 (49)	
Back pain + weakness	0 (0)	0.58 (8)	
Back pain + fracture	0 (0)	0.58 (8)	
Change in the treatment plan, % (n)			
Yes	33.33 (11)	10.18 (140)	<.001
No	54.55 (18)	85.60 (1177)	
Unknown	12.12 (4)	4.122 (58)	

CI, confidence interval; MRI, magnetic resonance imaging.

Table 2.
Frequency of unexpected MRI findings.

Types of unexpected findings on MRI	Frequency
Spine	
Nerve sheath tumor at S1 and S2 levels	1
Syrinx of the spinal cord	5
T2 hyperintensity at T12 suspicious for demyelination	1
Conjoined nerve roots	2
Filum terminale lipoma with conus	2
Mild epidural lipomatosis distal to L5 level	1
Myxopapillary ependymoma at L1 level	1
Thecal sac narrowing or distortion	4
Fluid in epidural space	1
Tethered cord with conus at L5	1
Retroperitoneal	
Renal cyst	2
Renal hypoplasia	2
Renal atrophy	2
Right-sided pelvic kidney	1
Hydronephrosis	1
Infra-peritoneal	
Adnexal cyst	3
Prominent polycystic ovaries	1
Distention of bladder to the umbilicus	1
Peritoneal	
Probable cholelithiasis	1
Splenomegaly	1
Vascular	
IVC occlusion	1

IVC, inferior vena cava; MRI, magnetic resonance imaging.

Table 3.
Prevalence of unexpected MRI findings.

Unexpected findings	Prevalence per 1000 MRI (95% confidence interval)
Total	2.48 (1.73, 3.43)
Peritoneal	0.14 (0.02, 0.51)
Infra-peritoneal	0.28 (0.07, 0.72)
Retroperitoneal	0.56 (0.25, 1.12)
Vascular	0.07 (0.002, 0.39)
Spine	1.34 (0.81, 2.10)

MRI, magnetic resonance imaging.

(Table 2). Among the spine-related findings, syrinx of the spinal cord was the most common (n = 5, 26.3%) followed by thecal sac narrowing or distortion (n = 4, 21.1%). Of the infra-peritoneal unexpected MRI findings, an adnexal cyst was the most common (n = 3, 60.0%). All retroperitoneal UFs were kidney-related: two instances of atrophy, two of hypoplasia, two of renal cysts, one of a pelvic kidney, and one of hydronephrosis. The single vascular unexpected MRI finding was the discovery of a chronic occlusion of the inferior vena cava with extensive venous collateralization.

The prevalence of unexpected MRI findings on a lumbar spine MRI is 2.5% (Table 3).

Table 4.
Factors influencing patients' presence of unexpected MRI findings.

Characteristics	Model 1	Model 2	Model 3
	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)
Age	0.96 (0.81, 1.15)	0.96 (0.81, 1.15)	1.01 (0.84, 1.23)
Male sex	0.98 (0.49, 1.93)	0.98 (0.50, 1.94)	1.04 (0.52, 2.06)
African American race	1.61 (0.75, 3.41)	1.57 (0.74, 3.32)	1.58 (0.74, 3.33)
Private insurance		2.92 (1.06, 8.04)	2.39 (0.86, 6.68)
Presence of back pain			0.94 (0.29, 3.09)
Presence of weakness			10.52 (1.71, 64.90)

Model 1: adjusted for age, sex, and African American race; Model 2: additionally adjusted for the presence of insurance type; Model 3: additionally adjusted for the presence of back pain and weakness as the reason for MRI investigation.
CI, confidence interval; MRI, magnetic resonance imaging.

Table 5.
Relationship between unexpected MRI findings and change in patient's treatment plan.

Change in treatment plan	Number of occurrences
Referral	
Neurosurgeon	6
Urologist/nephrologist	1
Change in imaging	
Ultrasound	1
Physical therapy prescribed	1
Epidural injection	1
Brace prescribed	1

MRI, magnetic resonance imaging.

Table 6.
Relationship between unexpected MRI findings and change in patient's treatment plan.

Characteristics	Model 1	Model 2	Model 3
	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)
Presence of unexpected MRI findings	3.57 (2.18, 5.83)	2.63	2.60

Model 1: adjusted for age, sex, and African American race; Model 2: additionally adjusted for insurance type; Model 3: additionally adjusted for the presence of back pain and weakness as the reason for MRI investigation.
CI, confidence interval; MRI, magnetic resonance imaging.

There was no significant association of age, sex, race, insurance type, presence of weakness, or presence of back pain with unexpected findings on MRI (Table 4).

Out of the 33 patients found to have UFs, 11 led to a change in treatment plan (33.3%) with specifics included in Table 5.

Patients with an unexpected MRI finding had a 2.60 times higher likelihood of experiencing a change in treatment plan compared with patients without UFs when adjusted for age, sex, African American race, government insurance, and presence of back pain and weakness as symptoms (Table 6). Back pain was not associated with an increased risk of UFs [risk ratio: 0.56 (95% CI: 0.22, 1.42)].

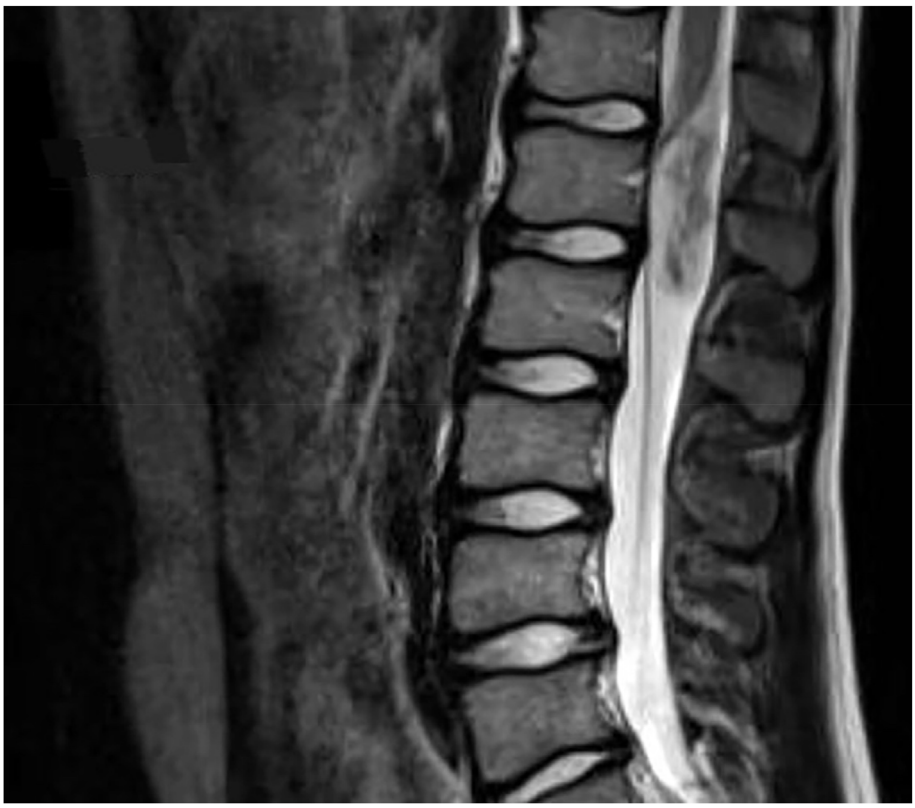

Figure 1. Unexpected finding of a myxopapillary ependymoma at the L1 level on magnetic resonance imaging.

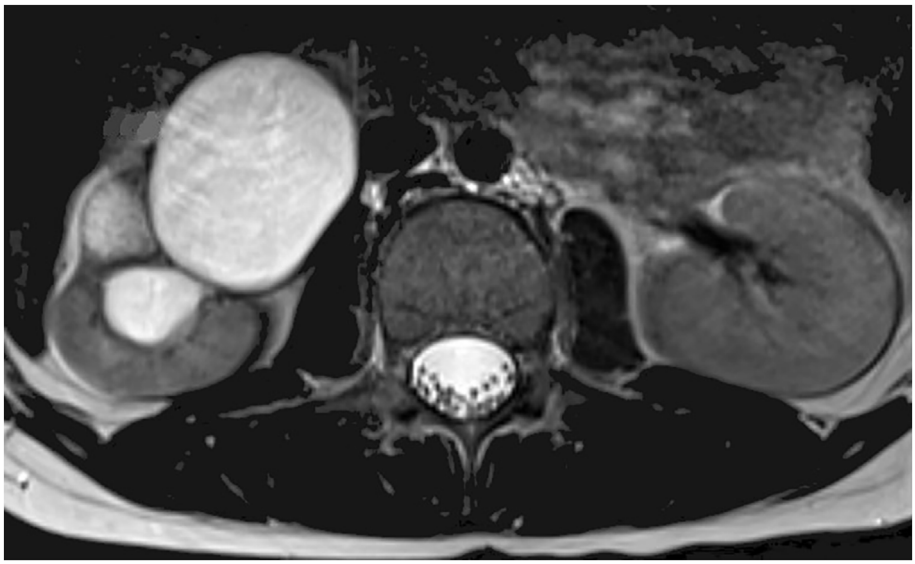

Figure 2. Unexpected finding of severe right-sided hydronephrosis suggesting ureteropelvic junction obstruction.

Discussion

The present study found that the overall rate of UFs on lumbar MRI in adolescents is noteworthy. The present literature reports a wide variety in the overall incidence of UFs. Schiettecatte et al. [8] found that in 540 children imaged by MRI secondary to suspected juvenile spondylarthritis, UFs were found twice as often as the potential sacroiliitis. Ramadorai et al. [9] investigated the prevalence of UFs in spine MRIs of pediatric patients and found degenerative disc disease in 19.6% of patients, disc herniations or protrusions in 2.9%, narrowed disc space in 33.7%, and endplate changes in 5.3%. In stark contrast, Urrutia et al. [10] investigated the prevalence of UFs in pediatric lumbar spine MRIs and found that none of their sample population had degenerative changes or disc herniation. Even within the same body region and imaging modality, there are vastly different reported rates of UF. Three studies investigating abdominopelvic UFs in lumbar MRIs reported a rate of 33.2% of UFs from 2076 MRIs ordered [5], 18.8% out of 1278 imaging studies [6], and a staggering 68.6% of patients with UFs out of 3000 imaging studies [7]. This high degree of variability points toward the continued need for studies to quantify UF rates and stratify by patient demographics and underlying conditions to determine why disparities in reported rates exist. This study further delineates rates of UFs within the

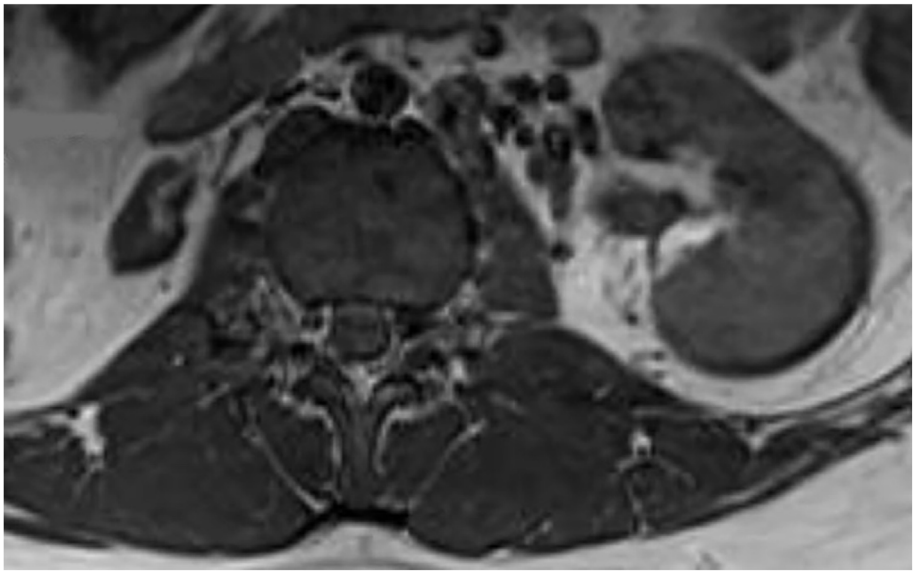

Figure 3. Unexpected finding of occlusion of the inferior vena cava with extensive venous collateralization.

Figure 4. Unexpected finding of right-sided pelvic kidney.

adolescent population receiving lumbar spine MRIs and seeks to describe the result of discovering these UFs. The lack of consistency in reported rates of UFs further highlights the need for continued studies in this area. This is the first study to investigate the rate of UFs in pediatric lumbar MRIs and their downstream effects on clinical relevance.

Our study found that while there was no significant difference in rates of UFs based on age, sex, race, or insurance type, a notable number of changes in treatment plans were based on the UFs. Change in treatment plan was investigated to determine the clinical relevance of UFs. Examples of changes in treatment plan were varied and included referral to neurosurgery for management of tethered cord, referral to an obstetrician for treatment of a large ovarian cyst, and epidural injections given for paracentral disc herniation, generally around the L4-S1 level. The highest rate of significant difference among rates of UFs based on reasoning for imaging was found in those who received MRI for back pain. The single vascular incidental MRI finding resulted in a referral to a vascular surgeon. The present study found no association between back pain and UFs. As UFs have the potential to be life threatening, it was paramount to attempt to discover the true rate at which they occur. Some of the more unique unexpected findings included an ependymoma at the L1 level (Fig. 1), hydronephrosis (Fig. 2), occlusion of the inferior vena cava (Fig. 3), and a pelvic kidney (Fig. 4).

A portion of the present literature suggests that UFs are clinically irrelevant. For example, of the 7.9% of musculoskeletal UFs found by de Vreede et al. [11] on pediatric pelvis MRIs, only 0.8% necessitated actual clinical evaluation. However, Quattrocchi et al. [7] reported 68.6% out of 3000 lumbar spine MRIs as having UFs; of these, 362 (17.6%) patients had either indeterminate or clinically important findings that required either further evaluation or clinical correlation. The present study found that 11 out of the 33 patients with UFs required a change in treatment plan. Currently, there is no standardization in how often UFs should be reported. We recommend that all UFs be reported, with the clinician then able to decide how to approach these findings with observation, referral to a subspecialist, or an intervention. The physician should also supply the radiologist with an adequate history and physical exam results to help guide their reading of the scan.

While some work has been done, further studies are needed to accurately ascertain the rate of UFs. A comprehensive systematic review of nine studies found widely differing rates of reported UFs depending on body part imaged and imaging modality [12]. While the existing literature largely reports low rates of UFs, an investigation of UFs in the middle ear and mastoid cavity on MRI found a much higher rate of 27.1% [13]. Another investigation discovered a surprising 41.5% of UFs in over-exposed chest radiographs of pediatric ICU patients [14]. Future studies should continue to investigate the rates at which UFs are found, and reported, in different hospital systems and in different patient populations as hospital protocol might influence how often radiologists actually report UFs. Additional studies could investigate how effective interventions are in the case of clinically significant UFs and gauge the benefit of these interventions by comparing the cost of additional workup and healthcare burden against improved patient morbidity, mortality, and quality of life. Further studies could also grade UFs based on body part imaged as different organ systems may have varying rates of UFs with vastly different clinical implications.

This study had some limitations. Due to its retrospective nature, we were unable to contact patients to more carefully determine if their unexpected MRI findings were directly related to their symptoms. Thus, the methodology for defining and reporting a change in treatment plan in future studies investigating UFs could be improved. Other studies have not reported on changes in treatment plans, so a strength of the present study is that it attempted to capture a clinical significance for UF instead of solely reporting the rate. Future studies should be prospective and include patient-reported outcome measures (PROMs). Another limitation of the present study was the lack of an asymptomatic control group, which would be paramount to determine what percentage of unexpected findings are truly the source of a patient's symptoms.

Conclusions

The overall number of unexpected findings in pediatric lumbar spine MRIs was 35 out of 1409 scans (2.3%) in 33 patients. Of these 33 patients, 11 (33.3%) required a change in treatment plan. Our hypothesis was partially correct; while a relatively small number of patients were found to have an UF, this number was insignificant. Additionally, a large portion of those patients went on to have a change in treatment plan, indicating that many of these UFs are noteworthy. Spine and retroperitoneal UFs were the most common. Clinicians should interpret UFs in the context of the patient's complaints and overall health, and be prepared to evaluate the UFs further or alter the treatment plan. In the rapidly shifting landscape of healthcare to a consumer, customer-focused model, this study does not advocate unwarranted studies to see if they might reveal an UF.

Consent for publication

The author(s) declare that no patient consent was necessary as no images or identifying information are included in the article.

Ethical approval

This study was approved by the institutional review board of the University of Tennessee Health Science Center (#20-07863-XP).

Author contributions

Bilal S. Siddiq: Writing – original draft, Data curation. **Anna Rambo:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Benjamin Sheffer:** Supervision, Methodology, Conceptualization. **Vania Ejiofor:** Data curation. **Abu M. Naser:** Formal analysis. **Trevor McGee:** Data curation. **William C. Warner:** Methodology, Conceptualization. **Derek M. Kelly:** Supervision, Methodology, Conceptualization.

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Declarations of competing interests

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Drs. Sheffer and Kelly receive royalties from Elsevier. Dr. Warner is an unpaid consultant for Medtronic Sofamor Danek and receives royalties from Saunders/Mosby-Elsevier and Wolters Kluwer Health-Lippincott Williams & Wilkins. Dr. Kelly is a board or committee member for POSNA. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Note

This study was performed at University of Tennessee Health Science Center-Campbell Clinic, Department of Orthopaedic Surgery and Biomechanical Engineering.

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