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REVIEW

Variations of the Piriformis and Sciatic Nerve With Clinical Consequence: A Review

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The deep gluteal region is often encountered when performing injections, when performing surgery such as total hip replacements, or diagnosing problems of this region or lower limbs using clinical or imaging techniques. Previously, the prevalence figures of piriformis and sciatic nerve anomalies have ranged from 1.5 to 35.8% in dissected specimens. This study systematically reviews and meta-analyses the prevalence of piriformis and sciatic nerve anomalies in humans using previously published literature. A further review is conducted regarding the anatomical abnormalities present in surgical case series of procedures for patients suffering from piriformis syndrome. After pooling the results of 18 studies and 6,062 cadavers, the prevalence of the anomaly in cadavers was 16.9%; 95% confidence interval (CI) 16.0–17.9%. The prevalence of the piriformis and sciatic nerve anomaly in the surgical case series was 16.2%, 95% CI: 10.7–23.5%. The difference between the two groups was not found to be significant 0.74%; 95% CI: −5.66 to 7.13; $P = 0.824$. Because of the high likelihood of an anomaly being present in a patient, clinicians and surgeons should be aware of the potential complications this anomaly may have on medical or surgical interventions. Furthermore, because the prevalence of the anomaly in piriformis syndrome patients is not significantly different from what is thought to be a normal population, it indicates that this anomaly may not be as important in the pathogenesis of piriformis syndrome as previously thought. Clin. Anat. 23:8–17, 2010.

Key words: piriformis; sciatica; sciatic nerve; common peroneal nerve; tibial nerve

INTRODUCTION

Spigelius, a Professor at Padua, in 16th century Italy, was the anatomist who first named the piriformis muscle (PM). The PM attaches proximally to the lateral border of the sacrum, the anterior aspect of the sacrum at the second, third, and fourth sacral segments, the superior margin of the greater sciatic notch and the sacrotuberous ligament. The PM then exits the pelvis in the greater sciatic foramen formed by the illium and attaches to the superior portion of the greater trochanter. Normally, the lumbosacral plexus is formed on the ventral side of the PM and four nerves (sciatic, pudendal, posterior femoral cutaneous, and inferior gluteal nerve) exit below the PM, whereas the superior gluteal nerve exits the pelvis above the PM. In a person with a variation of the normal anatomy, the sciatic nerve, or parts of it, may exit through or above the PM.

The relationships between the PM and sciatic nerve have been classified by Beaton and Anson using a six category classification system (Beaton and Anson, 1938). An anomalous relationship would be labeled as type ''B'' through to type ''F'' since type ''A'' is considered to be the normal relationship between the PM and the sciatic nerve (see Figs. 1–6).

These anomalies have been reported by several different authors, using cadavers of different races, age, and sex throughout the late 19th to the

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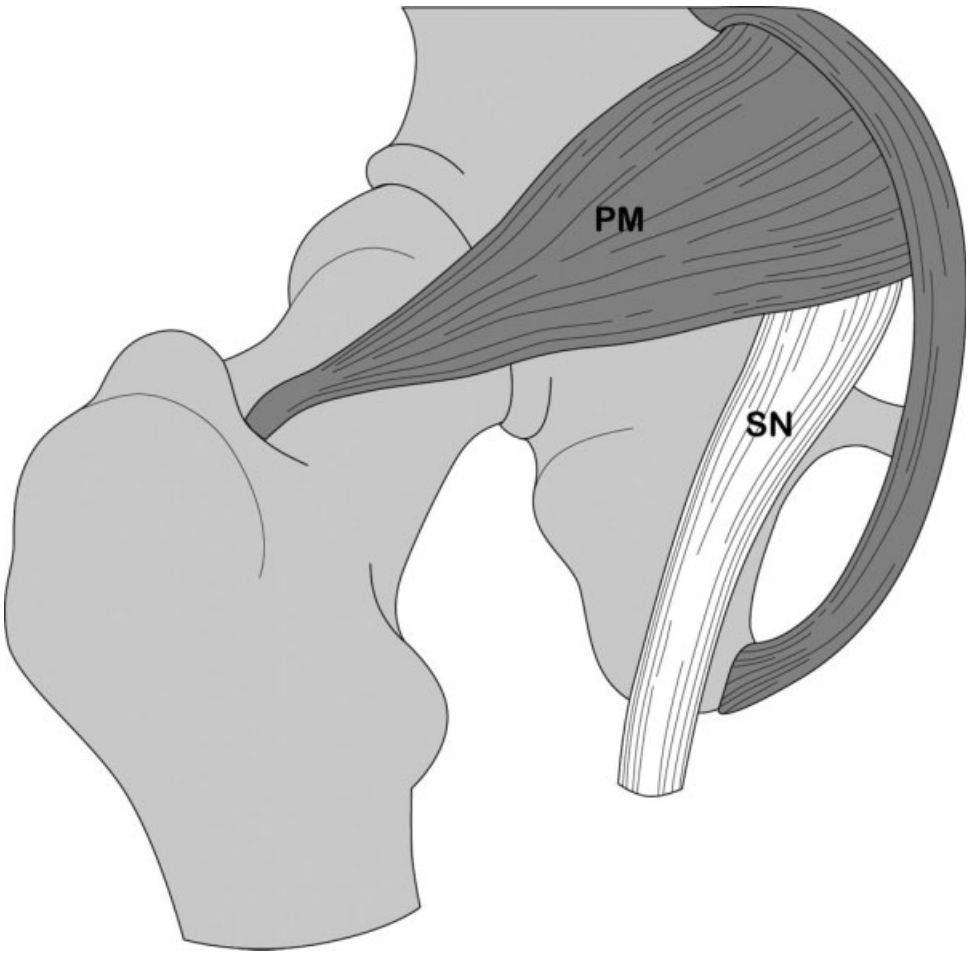

Fig. 1. Beaton and Anson type ''A.'' PM, piriformis muscle; SN, sciatic nerve.

21st centuries. Eighteen studies have been published, reporting more than 6,000 cases of this anomaly but the results are varied. The presence of these anomalies has ranged from 1.5 to 35.8% (Chiba, 1992; Benzon et al., 2003).

The piriformis syndrome is a nerve entrapment syndrome characterized by the entrapment of the sciatic nerve by PM hypertrophy, inflammation, or irritation (Barton, 1991; Papadopoulos and Khan, 2004). The clinical features are similar to intervertebral disc herniations with patients suffering from low back, buttock, and post-thigh pain, with occasional neurological symptoms such as foot drop, and dysasthesia. In some cases, it can be due to congenital variations of the PM and the sciatic nerve (Solheim et al., 1981; Chen and Wan, 1992; Ozaki et al., 1999; Kosukegawa et al., 2006). The type of anatomical variation present may reflect the clinical presentation of piriformis syndrome such that a split nerve (anomaly ''B,'' ''C,'' or ''E'') may only involve the common peroneal nerve, whereas anomaly ''D'' or ''F'' may involve the entire sciatic nerve.

Knowledge of the prevalence of piriformis and sciatic nerve anomalies is important for many clinical situations. These anomalies are relevant to clinicians performing procedures such as imaging guided injections of the PM, total hip arthroplasty, and piriformis tenotomy for piriformis syndrome. Furthermore, it may cause piriformis syndrome, post-tenotomy sciatica after total hip arthroplasty (Pokorny et al., 2006), or could be implicated as a cause of failed back surgery (Slipman et al., 2002).

At present, there are no accepted values for the prevalence of the anomaly and little evidence to support whether or not the anomaly causes piriformis syndrome or other types of sciatica. This study is a systematic review of dissections performed from the 19th to 21st centuries in which data is to be pooled to identify the most approximate true prevalence of this anomaly in normal limbs of cadavers. Furthermore, this data will be compared to pooled data from published case series of surgical procedures for piriformis syndrome to identify if there is a greater prevalence of this anomaly in populations that have

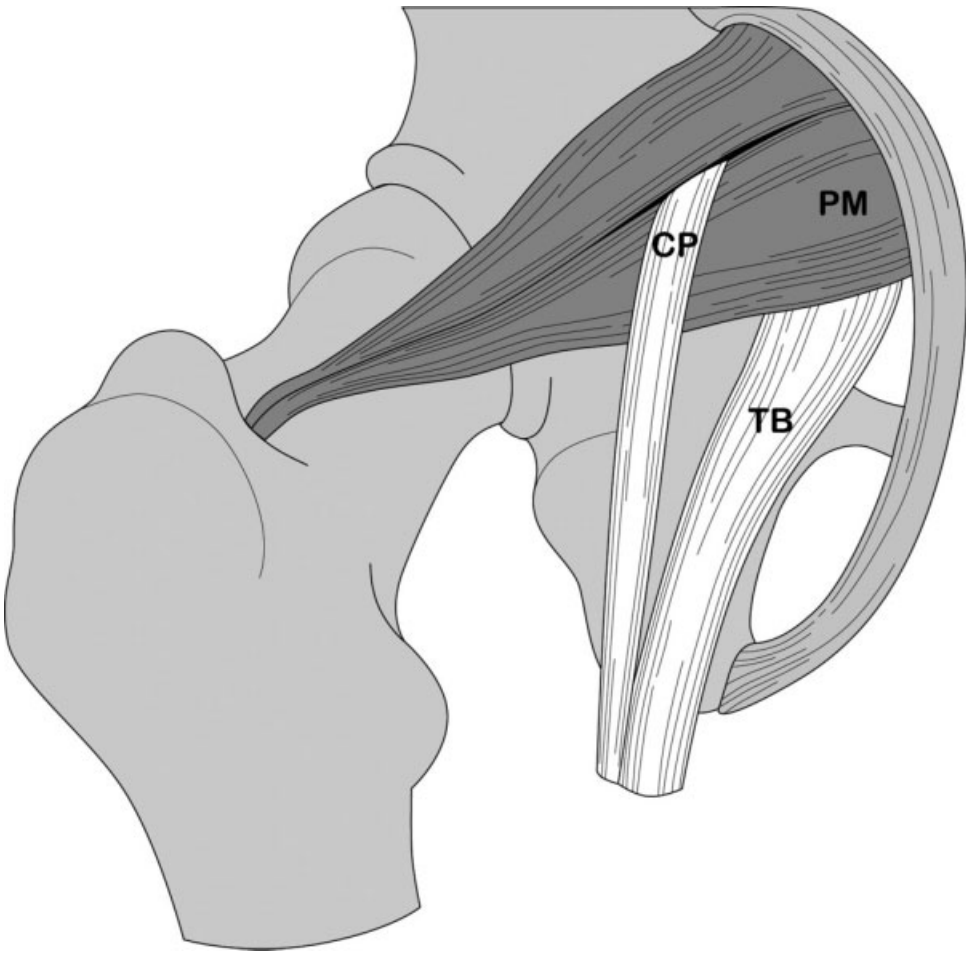

Fig. 2. Beaton and Anson type ''B.'' PM, piriformis muscle; TB, tibial nerve; CP, common peroneal nerve.

a diagnosis of piriformis syndrome compared to those populations that do not.

MATERIALS AND METHODS

Thirty anatomical textbooks and six databases were searched to find dissection reports that included statistics of the anomalies found in the deep gluteal region (Clericus and Mangetus, 1714; Douglas, 1777; Cheselden, 1778; Simmons, 1780; Aitken, 1786; Monro, 1788; Bell, 1798; Fyfe, 1800; Zuckerman, 1961; Hollinshead, 1967, 1982; Anson and McVay, 1971; Romanes, 1981; Tobias and Arnold, 1981; Joseph, 1982; Hobart, 1984; Rickenbacher et al., 1985; O'Rahilly, 1986; Woodburne and Burkel, 1988; Hall-Craggs, 1990; McMinn, 1990; Lumley et al., 1995; Williams et al., 1995; Ger et al., 1996; Clemente, 1997; Skandalakis, 2004; Snell, 2004; Agur and Dalley, 2005; Cramer and Darby, 2005; Moore and Dalley, 2006). In each textbook, the sections titled ''sciatic nerve'' and/or ''piriformis muscle'' were searched for documentation of dissection reports. MEDLINE, ISI Web of Knowledge, MEDITEXT, AMED, CINAHL, and EMBASE databases were searched using the search terms ''piriformis'' or ''pyriformis'' or ''piriformis syndrome'' or ''sciatic nerve.'' No publication year restrictions were imposed. Furthermore, the reference sections of the articles found were searched for additional reports.

The following summarizes the selection criteria used: (1) the study must be a report of piriformis and sciatic nerve anomalies in humans that reports such anomalies using a nominal scale similar to that described by Beaton and Anson (1938), i.e., A–F or 1–6; (2) the study must have been written in English; (3) no race, age, sex, journal, or publication year limitations were imposed. No efforts were made to search unpublished material.

Data extraction were performed by the author with no masking. Because of heterogeneity in each study's reporting process, it was difficult to obtain certain characteristics about the race, age, sex, and laterality (uni/bi) of the cadavers with anomalies.

As a second task, a search of surgical series was undertaken to identify the prevalence of the anomaly in patients who were undergoing surgery for piriformis syndrome. The searches included the databases

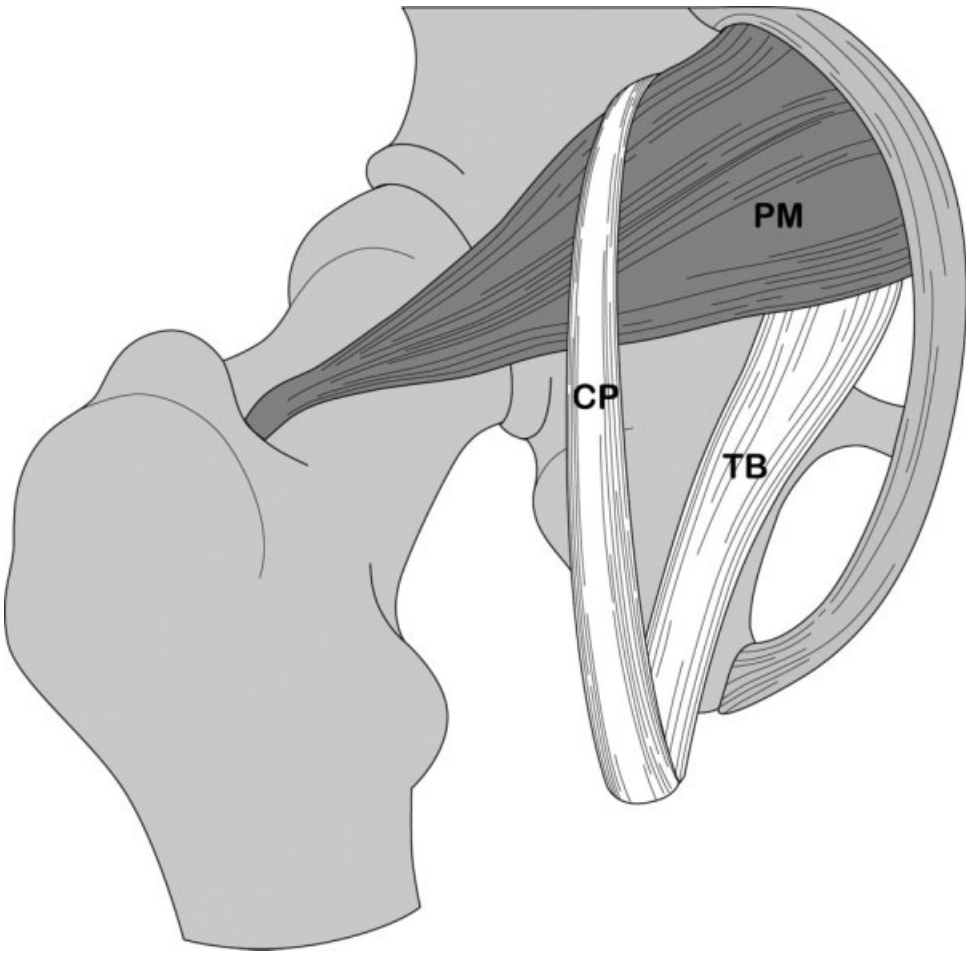

Fig. 3. Beaton and Anson type ''C.'' PM, piriformis muscle; TB, tibial nerve; CP, common peroneal nerve.

mentioned earlier and were searched using the terms ''piriformis syndrome'' and ''piriformis tenotomy.'' The references of all articles were searched to find any articles missed in the database search. To be included, the study must have been in the form of a surgical case series, must have reported the presence of the anomaly, and must have involved patients who were suffering from piriformis syndrome diagnosed according to any of the diagnostic criteria. Because there are no accepted diagnostic criteria for piriformis syndrome, no restrictions were imposed on the types of criteria used. This may be a source of inclusion bias for this part of the study.

RESULTS

The search resulted in 41,281 hits. After narrowing the search, 23 studies or data sets met the selection criteria. While reviewing the studies it was found that two studies (Beaton and Anson, 1937) were included in a textbook data set (Anson and McVay, 1971). Two further studies (Windisch et al., 2007; Guvencer et al., 2008) describing relationships between the piriformis and sciatic nerves were excluded because they did not describe the incidence of the nerve or part of the nerve piercing the PM. Thus, a total of 18 studies were included in the final analysis. After pooling the results of these studies, a total of 6,062 dissected limbs were reported. A total of 1,024 anomalous limbs were found which represents 16.9%, with a 95% confidence interval (CI) of 16.0–17.9%, of the pooled samples (see Table 1).

The type ''B'' anomaly was found most commonly and is present in 80.9% of anomalous deep gluteal regions. Type ''C'' is found in 7.6%, type ''D'' in 3.1%, type ''E'' and ''F'' in 0.5%. See Table 2.

Furthermore, only six studies included information about the occurrence of an anomaly bilaterally. In these studies 63.6%; 95% CI: 55.5–71.2 of anomalies studied occurred bilaterally. It is not known if the anomaly would be the same type on the contralateral side. Using the total prevalence (16.9%; 95% CI: 16.0–17.9) and the bilateral occurrence (63.6%; 95% CI: 55.5–71.2), the prevalence of at least one anomaly in this population of cadavers was found to be 23.1% with a 95% confidence interval of 21.6–25.6.

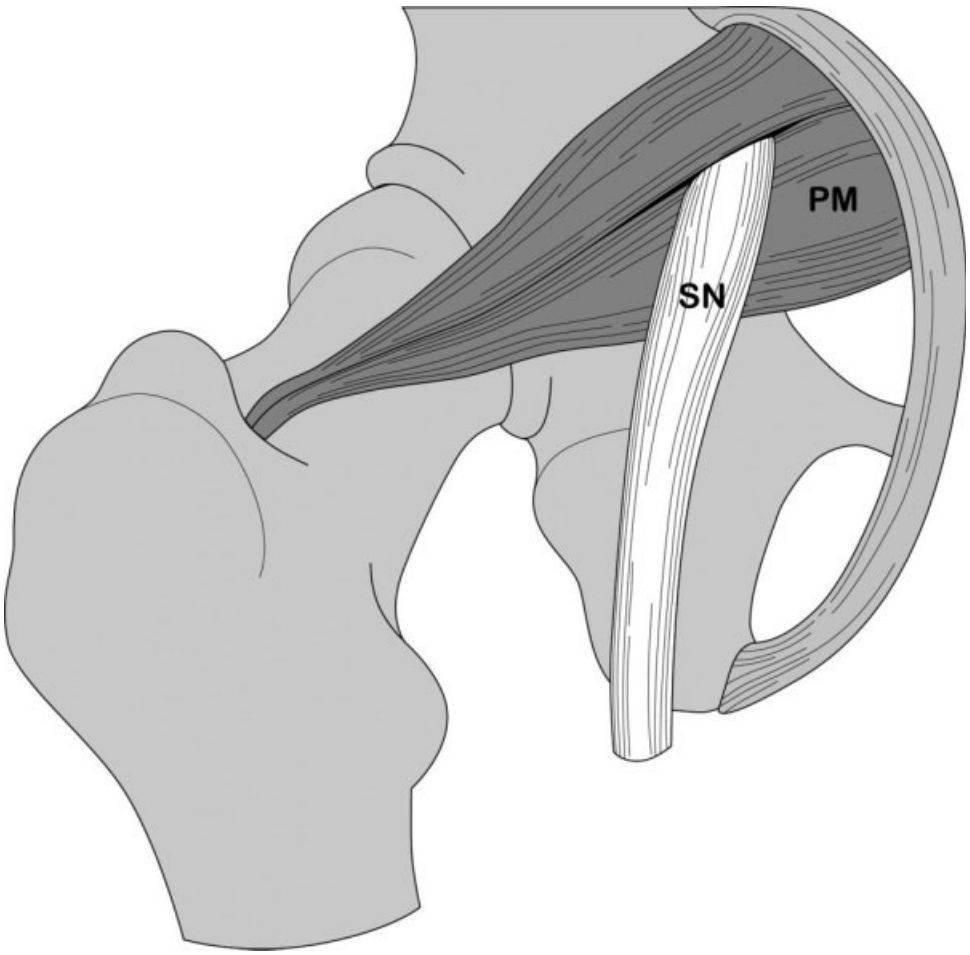

Fig. 4. Beaton and Anson type ''D.'' PM, piriformis muscle; SN, sciatic nerve.

A total of eight surgical case series were found which included a total of 130 cases of piriformis syndrome. Of the 130 surgical cases described, only 21 anomalies were found in patients with piriformis syndrome resulting in a prevalence of 16.2%; 95% CI: 10.7–23.5. The difference between the prevalence of the anomaly in surgical series and in cadaver series was not found to be significant (0.7% difference, 95% CI: -5.7, 7.1; $P = 82$).

An interesting finding which deserves closer examination than can be provided here is that the four largest cadaver series which reported individual anomaly types did not find types D, E, or F (Tables 2 and 3).

DISCUSSION

This systematic review and meta-analysis reviewed the prevalence figures from 18 anatomical studies of 6,062 limbs. This study also looked at the prevalence of this anomaly in surgical case series of patients with piriformis syndrome.

Assuming cadavers are valid representations of the normal living population, this study suggests that there is approximately a 23% chance that a particular person will have at least one anomaly of the PM and sciatic nerve on one or both sides. Furthermore, for a person undergoing a procedure involving the deep gluteal region, there is a 17% chance that an anomaly is present on that side. In that same person, there is an 81% chance that the anomaly is a type ''B'' anomaly. The majority (63.6%) of people with an anomaly on one side will also have an anomaly on the opposite side.

Although the confidence interval derived from these data is accurate, the clinical application of the narrow confidence interval (16.0–17.9%) to patients may be questioned. The width of the confidence interval is inversely proportional to the event rate in a particular population. In this population of $\sim$6,000 limbs, more than 1,000 limbs had an anomaly (event) thus leading to the narrow confidence interval. However, the wide range of incidence of anomalies across the various included studies (1.5–35.8%) indicates that perhaps a variable has not been controlled. The race and sex of the cadavers included in

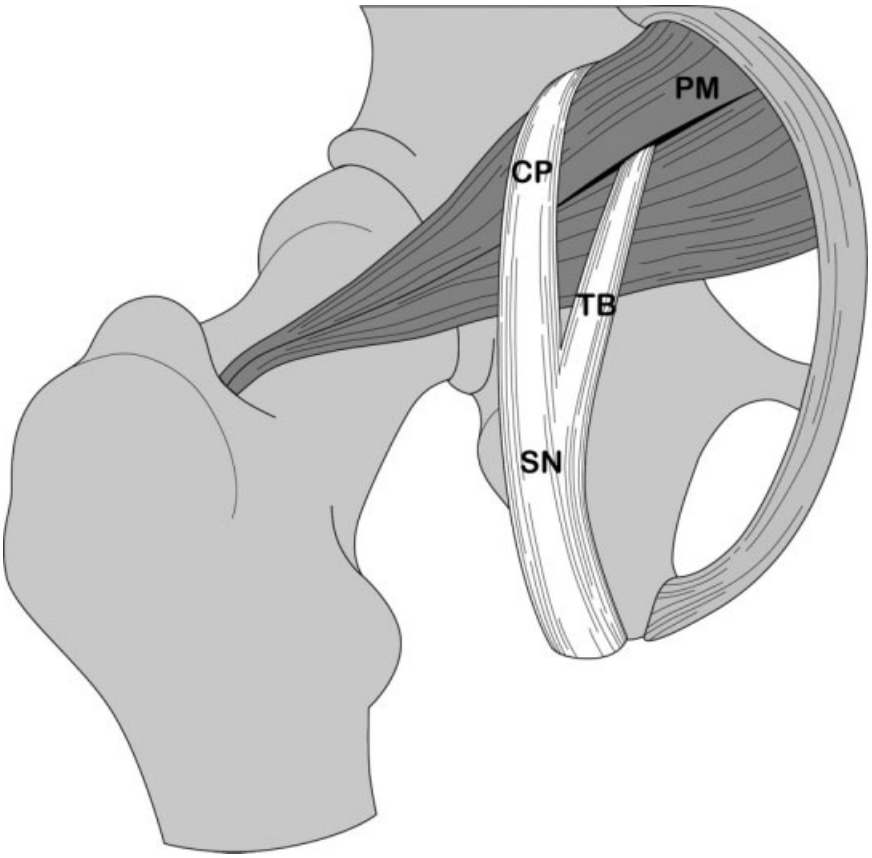

Fig. 5. Beaton and Anson type ''E.'' PM, piriformis muscle; SN, sciatic nerve; TB, tibial nerve; CP, common peroneal nerve.

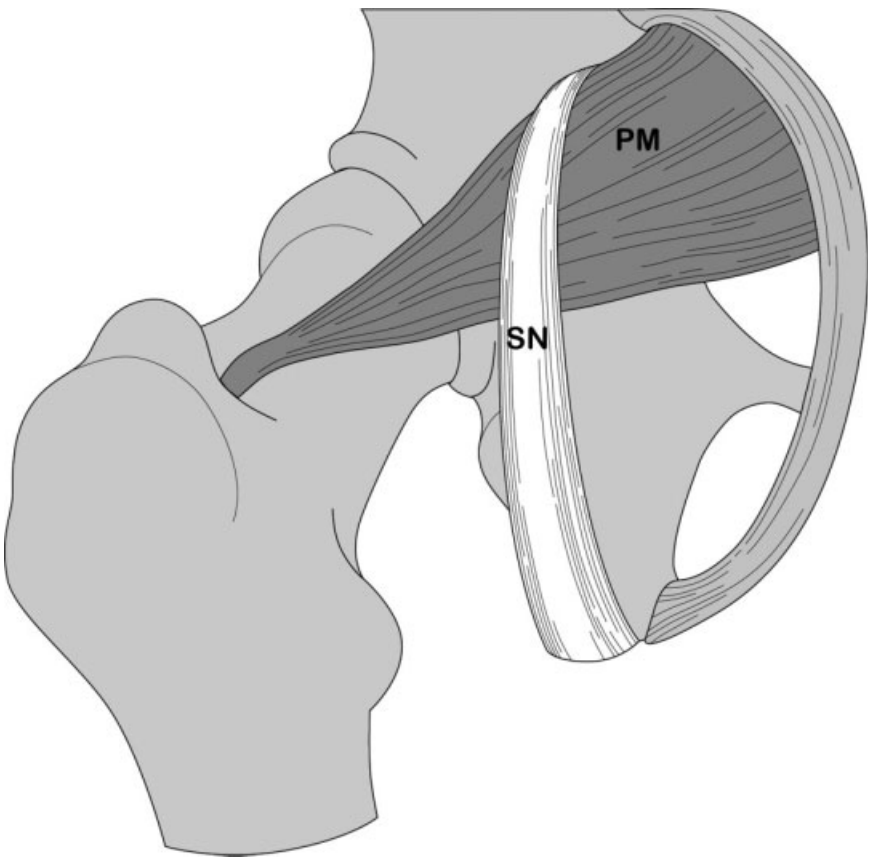

Fig. 6. Beaton and Anson type ''F.'' PM, piriformis muscle; SN, sciatic nerve.

TABLE 1. Characteristics of the Studies Included in this Review

Investigator	Number of cadavers (number of sides included)		Percentage of female cadavers	Laterality of the anomalies		Notes
				Unilateral	Bilateral (%)[a]	
Parsons and Keith, 1896	69	(138)	"Mostly men"	–	–	
Bardeen, 1901	123	(246)[b]	30	–	–	
Trotter, 1932	232	(464)	21	24	48 (63.6)	
Beaton and Anson, 1937[d]	60[b]	(120)	–	5	14 (73.6)	
Beaton and Anson, 1938[d]	60	(120)	–	3	2 (40.0)	Results presented in this study included data from a previous study
Ming-Tzu, 1941	70	(140)	"Mostly men"	22	24 (52.2)	
Misra, 1954	150	(300)	–	–	–	
Anson and McVay, 1971[c]	1,004[b]	(2,000)	–	–	–	This data set incorporated data from Beaton and Anson's two previous studies
Nizankowski et al., 1972	100	(200)	45	–	–	
Lee and Tsai, 1974	84	(168)	13	–	–	
Pecina, 1979	65	(130)	–	–	–	
Chiba, 1992	257	(511)	46	–	–	Three lower limbs of males excluded
Chiba et al., 1994	221	(442)	–	–	–	
Pokorny et al., 1998	51	(102)	–	–	–	
Fishman et al., 2002	38	(76)	–	1	10 (91.0)	This data was found in a study presenting data on the usage of H-reflex latencies for diagnosing piriformis syndrome
Benzon et al., 2003	36	(66)	–	1	0	In six cadavers, only one side was studied
Agur and Dalley, 2005	320[b]	(640)	–	–	–	
Ugrenovic et al., 2005	100	(200)	–	–	–	This study was carried out on human fetuses
Pokorny et al., 2006	91	(182)[b]	–	–	–	
Guvencer et al., 2009	25	(50)	0	–	–	
Total	See Table 3			56	98 (63.6)[e]	

[a]Total number of cadavers used as denominator.
[b]Information derived from data presented in the text.
[c]This study had inconsistencies in its reporting of statistics.
[d]Omitted from total as these results have been included in Anson and McVay (1971).
[e]95% Confidence interval = 55.5–71.2%.

this study could not be accounted for due to under-reporting in the included studies, and therefore, could not be controlled for. Therefore, the race and sex of a particular patient may have an effect on the chance of him or her having an anomaly.

Piriformis syndrome and other causes of non-discogenic back pain are considered to be the causes of failed back surgery (Slipman et al., 2002). Although it does not appear that piriformis syndrome is commonly caused by the anomalies mentioned here, there are a few cases reporting anomalies causing piriformis syndrome (Solheim et al., 1981; Chen and Wan, 1992; Ozaki et al., 1999; Kosukegawa et al., 2006). Because the symptoms and signs of intervertebral disc disease mimic those of piriformis syndrome, the diagnosis of intervertebral disc disease may serve as a red herring, causing unnecessary procedures to be performed on the lumbar spine.

In total hip arthroplasty, the severing of the tendon or tendons of the PM can cause retraction and atrophy of the muscle. If type "B," "D," or "E" anomalies are present, all or part of the sciatic nerve pierces the PM and retraction can cause sciatic nerve compression as the muscle retracts medially, pulling on the nerve. Pokorny et al. (2006) believe patients with anomaly types "B," "D," or "E" are particularly at risk of suffering from post-total hip arthroplasty sciatica.

Only a few case reports link the piriformis and sciatic nerve anomalies to piriformis syndrome (Solheim et al., 1981; Chen and Wan, 1992; Ozaki et al., 1999; Kosukegawa et al., 2006). If this anomaly was associated with piriformis syndrome, an

TABLE 2. Combined Results for Reported Piriformis and Sciatic Nerve Anomalies

Investigator	A	B	C	D	E	F	Total sides (total anomalous limbs)		Percent anomalous
Parsons and Keith, 1896	118	17	0	3	0	0	138	(20)	14.5
Bardeen, 1901	220	25	1	0	0	0	246	(26)	10.6
Trotter, 1932[a]	400	–	–	–	–	–	464	(64)	13.8
Ming-Tzu, 1941	92	46	0	2	0	0	140	(48)	34.3
Misra, 1954	262	18	12	8	0	0	300	(38)	12.7
Anson and McVay, 1971[b]	1,789	201	13	5	0	0	2,008	(219)	10.9
Nizankowski et al., 1972	181	8	3	5	3	0	200	(19)	9.5
Lee and Tsai, 1974	118	33	7	3	2	5	168	(50)	29.8
Pecina, 1979	102	27	1	0	0	0	130	(28)	21.5
Chiba, 1992	328	173	10	0	0	0	511	(183)	35.8
Chiba et al., 1994	285	148	9	0	0	0	442	(157)	35.5
Pokorny et al., 1998	82	14	4	2	0	0	102	(20)	19.6
Fishman et al., 2002[a]	65	–	–	–	–	–	76	(11)	14.5
Benzon et al., 2003	65	1	0	0	0	0	66	(1)	1.5
Agur and Dalley, 2005[b,c]	557	79	3	0	0	0	639	(82)	12.8
Ugrenovic et al., 2005	192	5	3	0	0	0	200	(8)	4.0
Pokorny et al., 2006[c]	144	26	8	4	0	0	182	(38)	20.9
Guvencer et al., 2009	38	8	4	0	0	0	50	(12)	24.0
Total	5,038	829	78	32	5	5	6,062	(1,024)	16.9[d]

[a]Individual types of anomalies were not mentioned, only the total anomalies recorded.

[b]Total number of cadavers (calculated) is different from the total number of cadavers reported (not shown).

[c]Numbers for each anomaly were calculated by using the percentage reported and the total number of sides in the study.

[d]95% Confidence Interval = 16.0–17.9%.

increased prevalence of the anomaly would be expected among patients suffering from piriformis syndrome. This report has found that patients diagnosed with piriformis syndrome appear as likely (reported here as 16.2%) as the normal population to have a piriformis and sciatic nerve anomaly. This finding may be subject to bias since the surgical patient population was small compared to the cadaveric population (130 compared to 6,062 cases). Because the surgical studies use no specific piriformis syndrome diagnostic criteria, and make no mention of patient follow-up or surgical success, it is possible that the patients in the samples were being misdiagnosed.

Broadhurst et al. (2004) describes a series of 27 patients undergoing ultrasound imaging of the buttock to see whether or not morphological changes in the PM can be identified in patients suffering from piriformis syndrome. They imaged both sides of the buttock using the unaffected side as a control. In this series, three anomalies were found, but all three were on the unaffected (control) side. However, this was the only such study to report such findings. This finding, along with our finding—that there may not be a higher prevalence of anomalies in surgical patients than in a normal population—suggests that piriformis and sciatic anomalies may not be as important to the pathophysiology of piriformis syndrome as previously thought.

These anatomical abnormalities have not been named and there is no set terminology, there-

TABLE 3. Prevalence of Piriformis and Sciatic Nerve Anomalies in Published Surgical Case Series for Piriformis Syndrome

	Number of surgeries performed	Amount of anomalies reported	(%)
Fishman et al., 2002	43	6	(14.0)
Indrekvam and Sudmann, 2002	19	4	(21.1)
Foster, 2002	7	0	
Chin et al., 2005	30	7	(23.3)
Benson and Shutzer, 1999	15	1	(6.7)
Meknas et al., 2003	6	0	
Pecina et al., 2008	10	3	(30)
Total	130	21	(16.2)[a]

[a]95% Confidence interval = 10.7–23.5%.

fore, I recommend using the term ''piriformis-sciatic anomaly.''

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