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The predictive role of the posterior tibial tendon cross-sectional area in early diagnosing posterior tibial tendon dysfunction

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Abstract

A hypertrophied posterior tibial tendon (PTT) has been considered to be an important morphologic parameter of PTT dysfunction (PTTD). Previous research has demonstrated that the PTT thickness (PTTT) is correlated with early signs of PTTD. However, the thickness is different from hypertrophy. Thus, we devised the PTT cross-sectional area (PTTCSA) as a new predictive parameter for diagnosing the PTTD.

The PTT data were acquired from 14 patients with PTTD and from 20 normal individuals who underwent ankle magnetic resonance imaging. We measured the PTTT and PTTCSA at the PTT on the ankle magnetic resonance imaging.

The mean PTTT was 2.43 ± 0.39 mm in the normal group and 3.40 ± 0.42 mm in the PTTD group. The average PTTCSA was 16.10 ± 4.27 mm^2 in the normal group and 26.93 ± 4.38 mm^2 in the PTTD group. The receiver operator characteristic analysis curve demonstrated that the highest predictive value of the PTTT was 3.07 mm, with 85.7% sensitivity, 85.0% specificity. The highest predictive value of the PTTCSA was 22.54 mm^2, with 92.9% sensitivity, 90.0% specificity.

Our findings suggest that the PTTCSA was a more valid predictor of PTTD, even though the PTTT and PTTCSA were both significantly associated with PTTD.

Abbreviations: AMRI = Ankle Magnetic resonance imaging, PTT = posterior tibial tendon, PTTCSA = posterior tibial tendon cross-sectional area, PTTD = posterior tibial tendon dysfunction, PTTT = posterior tibial tendon thickness, ROC = receiver operating characteristic.

Keywords: anatomy, cross-sectional, area under the curve, posterior tibial tendon dysfunction, tendons, receiver operating characteristic curve

1. Introduction

The function of the posterior tibial tendon (PTT) is to maintain a longitudinal arch, invert the foot, and maintain the hindfoot. PTT dysfunction (PTTD) results when the tendon is torn or inflamed.[1,2] As a result, the PTT may not be able to provide support and stability for the arch of the foot, resulting in acquired flatfoot. An acute injury can tear the PTT or cause it to become inflamed. Repetitive use of the PTT can also tear it. For instance, people who do active sports, such as soccer, tennis, or basketball, may have tears of the PTT from overuse. Once the PTT becomes torn or inflamed, the arch will slowly collapse over time. Additional risk factors include diabetes, hypertension, and obesity.[3–7] Most patients can be treated without surgery, using braces and orthotics. If braces and orthotics do not relieve the discomfort, surgery can be an effective alternative method to help the maintenance of the PTT. Surgery might be repairing a simple tear or removing the inflamed tissue. In several cases, the cause of the acquired flatfoot deformity is PTTD accompanying a PTT injury.[2,8,9] Thus early diagnosis and treatment are very important.

Ankle Magnetic resonance imaging (AMRI) helps the analysis of the pathologic disorders of the PTT.[9–11] Most specialists also consider the AMRI findings when they evaluate the morphology of the PTT for deciding on treatment choices. Previous research evaluated the PTT using one measurement at the "middle" of the PTT.[12] However, partial damage and asymmetrical inflammatory thickening can occur anywhere in the PTT. Accordingly, measurement bias can occur frequently. In contrast to the PTT thickness (PTTT), the PTT cross-sectional area (PTTCSA) does not suffer from this measurement mistake, because the PTTCSA measures the cross-sectional area of the PTT. Therefore, to evaluate the inflammatory reaction of the PTT, we devised the PTTCSA as a new morphological diagnostic parameter. We

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assumed that the PTTCSA is an important morphologic parameter in PTTD diagnosis. So, we used AMRI to compare the PTTT and PTTCSA between PTTD patients and normal subjects.

2. Methods

2.1. Patients

The retrospective data of this research were approved by Catholic Kwandong University Institutional Review Board (CKU IRB) center (CKU IRB number: IS19RIS10049). We reviewed individuals who visited the orthopedic clinic with ankle and foot pain from October 2014 to December 2018 and who had taken AMRI

The inclusion criteria of the PTTD group were as follows:

(1) pain, typically around the inside of the ankle and foot;
(2) swelling, warmth, and redness along the inside of the foot and ankle
(3) pain that worsens during activity;
(4) flattening of the foot;
(5) inward rolling of the ankle; and
(6) turning out of the toes and foot.

We excluded subjects if patients had any of the following disorders:

(1) past surgical history of the ankle;
(2) peroneal disorder;
(3) plantar fasciitis; and
(4) any other neuromuscular disorder.

A total of 14 individuals who met our enrollment criteria were included after PTTD diagnosis was confirmed by a board-certified experienced musculoskeletal radiologist.

There were 9 (64.29%) male patients and 5 (35.71%) female patients, with an average age of 38.64 ± 12.46 years (range, 19 to 57 years) (Table 1). To compare the PTTT and PTTCSA between patients and normal individuals, we enrolled healthy subjects.

Table 1

Comparison of the demographic data of the control and PTTD groups.

Variable	Control Group n = 20	PTTD Group n = 14	Statistical significance
Gender, men/women	10/10	9/5	NS
Ankle image, Rt./Lt.	10/10	6/8	NS
Age, yr	41.15 ± 14.72	38.64 ± 12.46	NS
PTTT, mm	2.43 ± 0.39	3.40 ± 0.42	$P < .001$
PTTCSA, mm^2	16.10 ± 4.27	26.93 ± 4.38	$P < .001$

Data represent the mean ± standard deviation (SD) or the numbers of patients.
NS = not statistically significant ($P > .05$), PTTCSA = posterior tibial tendon cross-sectional area, PTTD = posterior tibial tendon dysfunction, PTTT = posterior tibial tendon thickness.

The normal subjects were individuals who wanted to have AMRIs themselves for a medical examination. In the normal group, 20 individuals (10 males and 10 females) were enrolled, with an average age of 41.15 ± 14.72 years (range, 19 to 63 years).

2.2. Imaging parameters

AMRI analysis was done using a 3T MRI (Siemens health care) and 3T Philips Insignia scanners (Eindhoven, Netherlands). For all AMRI examinations, we acquired transverse T1-weighted turbo-spin echo (TSE) proton-density (PD) images using an intersection gap of 0.9 mm, 150 × 150 cm field of view, repetition time (TR) 3770 ms of/echo time (TE) 38 ms, 448 × 448 matrix, and > 3 ETL, a slice thickness of 3 mm.

2.3. Image analysis

The corresponding author, who was blinded to the group of the ankles, measured the PTTT and PTTCSA. We acquired transverse T1-weighted AMR images at the thickest level of the PTT. We measured the PTTT and PTTCSA on AMRI using an image-analysis program (INFINET, Incheon city, Republic of Korea). (Fig. 1 A, B). The PTTCSA was measured as the cross-sectional

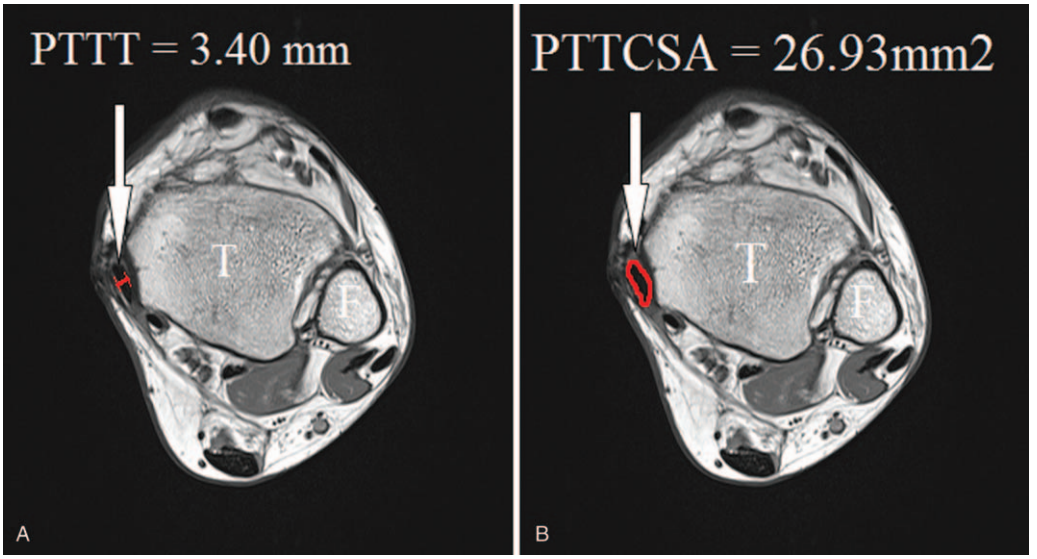

Figure 1. Both posterior tibial tendon thickness (PTTT) (white arrow) (A) and posterior tibial tendon cross-sectional area (PTTCSA) (white arrow) (B) in the posterior tibial tendon deficiency were measured on AMRI proton density T1 weighted images. T = tibia; F = fibula.

area of the margin of the PTT at the most marked portion of hypertrophy in the AMR images.

2.4. Statistical analysis

We compared both the PTTT and PTTCSA between the PTTD and the normal groups using unpaired *t*-tests. Receiver operating characteristic (ROC) curves were used to compare and describe the diagnostic performances of the PTTT and PTTCSA methods; and a $P < .05$ was considered significant. Statistical analysis was performed with SPSS (IBM/SPSS, Inc., Chicago, IL) for Windows, version 22.

3. Results

Demographic data were not significantly different between the 2 groups (Table 1). The average PTTT was 2.43 ± 0.39 mm in the normal group and 3.40 ± 0.42 mm in the PTTD group. The average PTTCSA was $16.10 \pm 4.27\,mm^2$ in the normal group and $26.93 \pm 4.38\,mm^2$ in the PTTD group. The PTTD patients had significantly higher PTTT ($P < .001$) and PTTCSA ($P < .001$) than did the normal subjects (Table 1). A ROC analysis demonstrated that the area under the curve (ACU) was 0.92 (95% CI, 0.84-1.00) in PTTT and 0.95 (95% CI, 0.87-1.00) in PTTCSA (Fig. 2). The best cut-off value for PTTD was 3.07 mm with a sensitivity of 85.7% and a specificity of 85.0% in PTTT (Table 2), and $22.54\,mm^2$ with a sensitivity of 92.9% and a specificity of 90.0% in PTTCSA (Table 3).

Table 2

Sensitivity and specificity of each cut-off point of the PTTT.

PTTT (mm)	Sensitivity (%)	Specificity (%)
1.08	100	0
2.33	100	25
2.59	92.9	50
3.07[a]	85.7	85
3.31	57.1	100
3.77	21.4	100

PTTT = posterior tibial tendon thickness.

[a] The best cut-off point on the receiver operating characteristic (ROC) curve.

4. Discussion

The PTT that plays an important role in normal hindfoot function lies beneath the flexor retinaculum and close to the medial malleolus, which binds the tendon to the bone. Since the PTT is the important supporter of the medial aspect of the foot, lack of PTT function results in a gradual flattening of the longitudinal arch of the foot, and, eventually, a hindfoot valgus deformity occurs.[9] Patients suffering from PTTD may have medial ankle pain, clinically. In cases with an inflammatory reaction, there can be edema and tenderness of the PTT. These are most likely to be observed in the distal portion, which is the area most commonly involved in PTT lesions.[4] Because the deformity will develop and progress with delayed or misleading diagnosis, image modalities of acquired flatfoot deformity caused by PTTD require an exact approach to ensure the best therapeutic

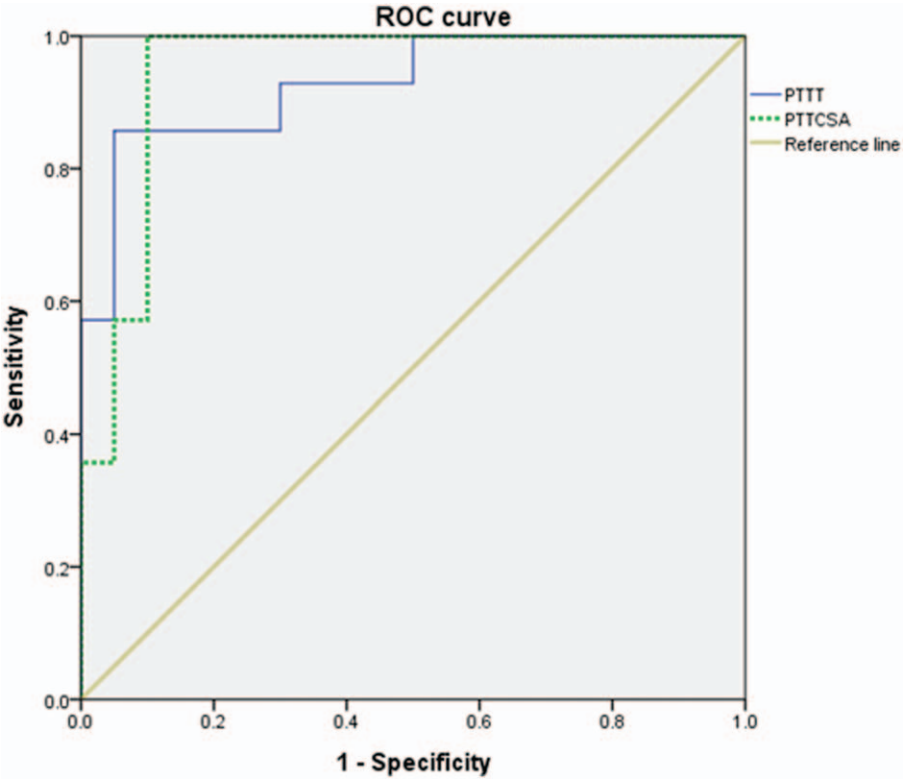

Figure 2. Receiver operating characteristic (ROC) curve of PTTT and PTTCSA for predicting PTTD. The best cut-off point was 3.07 mm in PTTT versus $22.54\,mm^2$ in PTTCSA, with a sensitivity of 85.7% versus 92.9%, a specificity of 85.0% versus 90.0% and an AUC of 0.92 versus 0.95, respectively. AUC = area under the curve, PTTT = posterior tibial tendon thickness, PTTCSA = posterior tibial tendon cross-sectional area, PTTD = posterior tibial tendon dysfunction.

Table 3

Sensitivity and specificity of each cut-off point of the PTTCSA.

PTTCSA (mm^2)	Sensitivity (%)	Specificity (%)
11.28	100	5
15.08	100	55
17.42	100	75
22.54[a]	92.9	90
23.20	78.6	90
28.54	35.7	100

PTTCSA = posterior tibial tendon cross-sectional area.
[a] The best cut-off point on the receiver operating characteristic (ROC) curve.

management. There are multiple available imaging modalities such as AMRI, ultrasonography, bone scintigraphy and high-resolution ultrasound.[13–19] However, the diagnosis of PTTD is still not easy because of the absence of a reliable objective diagnostic parameter. Conti et al. used AMRI to divide PTTD into three grades and insisted that this new classification could be important in predicting the surgical consequences.[20] They concluded that the need for surgical treatment declined when the classification grade was lower. However, surgery is no longer recommended these days, and the usefulness of the classification is not proved.

The talonavicular coverage angle was measured by Sangeorzan et al[21] They have demonstrated that an improvement of 26 degrees can be achieved via lateral column lengthening; however, there was no mention about the actual angle of PTT. Younger et al have demonstrated that the distance was 17.5 mm in a normal situation and 6.3 mm when symptoms of flatfoot were observed.[22] However, they did not evaluate the PTT itself. Acquired flatfoot is only a result, not a cause. Chen et al. reported that the mean diameter of the tendon in the unaffected foot was 3.30 ± 0.34 mm and that of the PTT diameter was 3.64 ± 0.35 mm.[12] They concluded that the increased ratio of the peritendinous area was significantly greater than for the tendinous portion in symptomatic PTT ($P < .01$). Their measurements were acquired at the middle level between the insertion sites. However, the morphology of the PTT injury can differ, in such ways as having an irregular tendon torn, a wavy or curved contour, elongation, and different signal intensities within the PTT.[23,24] Thus, measuring mistakes could occur frequently.

In this study, we assumed that the cross-sectional tendon area of the PTT on AMRI may predict PTTD better since it would lower measurement mistakes comparing to the thickness of PTT. And we used T1 weighted AMR images because the tendons are clearly seen on AMRI as hypointense anatomies on T1 images. T1 weighted images provide excellent anatomical images at the location of tendon injury.[25–27] Our current results show that the AUC value of ROC for predicting PTTD was 0.95 with a sensitivity of 92.9% and a specificity of 90.0% in PTTCSA, and 0.92 with a sensitivity of 85.7% and a specificity of 85.0% in PTTT. These results suggest that the PTTCSA is a better predictor of PTTD than is the PTTT.

There were multiple limitations to this research. First, alternative diagnostic skills to evaluate PTTD, such as ultrasound analysis[28–34], high-resolution ultrasound, and a grading system, have been used to discriminate PTTD. However, in this research, we assessed only the measurement of the PTTCSA and PTTT on AMRI. Second, there might be a tiny bias associated with measuring the PTTCSA and PTTT on AMRI. Even though we tried to calculate morphologic parameters in the best-shown transverse image of the PTT, the transverse images we calculated to measure the PTTCSA could be irregular because of the cutting level in the AMRI. Third, PTTD was evaluated and classified using 3 grades: in Grade 1, the high signal intensity area is observed and the tendon has become thicker; in Grade 2, the intramural degeneration and several high signal intensity areas are present and the tendon has become thinner; and in Grade 3, the discontinuity has appeared.[9] However, we focused only on the thickened PTT (Grade 1) because our aim was to enable early diagnosis of PTTD to prevent acquired flatfoot. Fourth, the design of this research was a retrospective case-control evaluation. Despite these limitations, this research is the first study to report that PTTCSA is associated with PTTD.

In conclusion, even though the PTTCSA and PTTT were both significantly associated with PTTD, the PTTCSA was a more highly sensitive diagnostic parameter for PTTD than was PTTT. We demonstrated the best cut-off point of the PTTCSA as 22.54 mm^2 with a sensitivity of 92.9% and a specificity of 92.0%. When assessing PTTD patients, doctors should carefully evaluate the PTTCSA as a new objective parameter.

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References

[1] Adelman VR, Szczepanski JA, Adelman RP. Radiographic evaluation of endoscopic gastrocnemius recession, subtalar joint arthroereisis, and flexor tendon transfer for surgical correction of stage II posterior tibial tendon dysfunction: a pilot study. J Foot Ankle Surg 2008;47:400–8.
[2] Didomenico L, Stein DY, Wargo-Dorsey M. Treatment of posterior tibial tendon dysfunction without flexor digitorum tendon transfer: a retrospective study of 34 patients. J Foot Ankle Surg 2011;50:293–8.
[3] Alvarez RG, Marini A, Schmitt C, et al. Stage I and II posterior tibial tendon dysfunction treated by a structured nonoperative management protocol: an orthosis and exercise program. Foot Ankle Int 2006;27:2–8.
[4] Arnoldner MA, Gruber M, Syre S, et al. Imaging of posterior tibial tendon dysfunction–Comparison of high-resolution ultrasound and 3T MRI. Eur J Radiol 2015;84:1777–81.
[5] Chhabra A, Soldatos T, Chalian M, et al. 3-Tesla magnetic resonance imaging evaluation of posterior tibial tendon dysfunction with relevance to clinical staging. J Foot Ankle Surg 2011;50:320–8.
[6] Ling SK, Lui TH. Posterior tibial tendon dysfunction: an overview. Open Orthop J 2017;11:714–23.
[7] Zejjari H, Rachid K. Posterior tibial tendon dysfunction by bone imprisonment. Pan Afr Med J 2016;24:218.
[8] Hasler P, Hintermann B, Meier M. Posterior tibial tendon dysfunction and MR imaging in rheumatoid arthritis. Rheumatol Int 2002;22:38–40.
[9] Ikoma K, Hara Y, Kido M, et al. Relationship between grading with magnetic resonance imaging and radiographic parameters in posterior tibial tendon dysfunction. J Foot Ankle Surg 2017;56:718–23.
[10] Blasimann A, Eichelberger P, Brulhart Y, et al. Non-surgical treatment of pain associated with posterior tibial tendon dysfunction: study protocol for a randomised clinical trial. J Foot Ankle Res 2015;8:37.
[11] Hogan JF. Posterior tibial tendon dysfunction and MRI. J Foot Ankle Surg 1993;32:467–72.

[12] Chen YJ, Liang SC. Diagnostic efficacy of ultrasonography in stage I posterior tibial tendon dysfunction: sonographic-surgical correlation. J Ultrasound Med 1997;16:417–23.
[13] Chae WS, Kim SH, Cho SH, et al. Reduction in mechanical allodynia in complex regional pain syndrome patients with ultrasound-guided pulsed radiofrequency treatment of the superficial peroneal nerve. Korean J Pain 2016;29:266–9.
[14] Kim MS, Jeong TY, Cheong YS, et al. Effect of epidural corticosteroid injection on magnetic resonance imaging findings. Korean J Pain 2017;30:281–6.
[15] Shin SH, Kim SJ. Bone scintigraphy in patients with pain. Korean J Pain 2017;30:165–75.
[16] Dass RM, Kim E, Kim HK, et al. Alcohol neurolysis of genicular nerve for chronic knee pain. Korean J Pain 2019;32:223–7.
[17] Kim SY, Cheon JH, Seo WJ, et al. A pictorial review of signature patterns living in musculoskeletal ultrasonography. Korean J Pain 2016;29:217–28.
[18] Patil S, Iyengar AR, Kotni RM, et al. Evaluation of efficacy of ultrasonography in the assessment of transcutaneous electrical nerve stimulation in subjects with myositis and myofascial pain. Korean J Pain 2016;29:12–7.
[19] Lee HJ, Lee CS, Yoo Y, et al. Complex regional pain syndrome in the young male population: a retrospective study of 200 Korean young male patients. Korean J Pain 2019;32:292–300.
[20] Conti S, Michelson J, Jahss M. Clinical significance of magnetic resonance imaging in preoperative planning for reconstruction of posterior tibial tendon ruptures. Foot Ankle 1992;13:208–14.
[21] Sangeorzan BJ, Mosca V, Hansen ST. Effect of calcaneal lengthening on relationships among the hindfoot, midfoot, and forefoot. Foot Ankle 1993;14:136–41.
[22] Younger AS, Sawatzky B, Dryden P. Radiographic assessment of adult flatfoot. Foot Ankle Int 2005;26:820–5.
[23] Soliman SB, Spicer PJ, van Holsbeeck MT. Sonographic and radiographic findings of posterior tibial tendon dysfunction: a practical step forward. Skeletal Radiol 2019;48:11–27.
[24] Walley KC, Roush EP, Stauch CM, et al. Three-dimensional morphometric modeling measurements of the calcaneus in adults with stage iib posterior tibial tendon dysfunction: a pilot study. Foot Ankle Spec 2018;12:316–21.
[25] Kuhn JP, Hernando D, Meffert PJ, et al. Proton-density fat fraction and simultaneous R2* estimation as an MRI tool for assessment of osteoporosis. Eur Radiol 2013;23:3432–9.
[26] Zand KA, Shah A, Heba E, et al. Accuracy of multiecho magnitude-based MRI (M-MRI) for estimation of hepatic proton density fat fraction (PDFF) in children. J Magn Reson Imaging 2015;42:1223–32.
[27] Lee S, Cho HR, Yoo JS, et al. The prognostic value of median nerve thickness in diagnosing carpal tunnel syndrome using magnetic resonance imaging: a pilot study. Korean J Pain 2020;33:54–9.
[28] An D, Black ND, Tierney S, et al. The impact of an ultrasound-guided regional anesthesia workshop on participants' confidence levels and clinical practice. Korean J Anesthesiol 2020; https://doi.org/10.4097/kja.20203. [Epub ahead of print]
[29] Baek SJ, Lee JW, Chung S, et al. Clinical usefulness of ultrasound as an early diagnostic tool for neuroleukemiosis. Korean J Anesthesiol 2020; https://doi.org/10.4097/kja.2012820211. [Epub ahead of print]
[30] Ekinci M, Ciftci B, Alici HA, et al. Ultrasound-guided rhomboid intercostal block effectively manages myofascial pain. Korean J Anesthesiol 2020;https://doi.org/10.4097/kja.20211. [Epub ahead of print]
[31] Kim TE, Tsui BCH. Simulation-based ultrasound-guided regional anesthesia curriculum for anesthesiology residents. Korean J Anesthesiol 2019;72:13–23.
[32] Mudumbai SC, Kim TE, Howard SK, et al. An ultrasound-guided fascia iliaca catheter technique does not impair ambulatory ability within a clinical pathway for total hip arthroplasty. Korean J Anesthesiol 2020;69:368–75.
[33] Finneran JJ, Gabriel RA, Swisher MW, et al. Ultrasound-guided percutaneous intercostal nerve cryoneurolysis for analgesia following traumatic rib fracture: a case series. Korean J Anesthesiol 2019.
[34] Okmen K, Okmen BM. Ultrasound-guided anterior quadratus lumborum block for postoperative pain after percutaneous nephrolithotomy: a randomized controlled trial. Korean J Anesthesiol 2020; 73:44–50.