Received:
20 June 2016

Revised:
11 August 2016

Accepted:
20 September 2016

<http://dx.doi.org/10.1259/bjr.20160554>

Cite this article as:

Park HJ, Lee SY, Choi SH, Ahn JH, Park SJ, Park JH, et al. Comparison of oblique coronal images in knee of three-dimensional isotropic T_2 -weighted turbo spin echo MRI versus two-dimensional fast spin echo T_2 -weighted sequences for evaluation of posterior cruciate ligament injury. *Br J Radiol* 2016; **89**: 20160554.

FULL PAPER

Comparison of oblique coronal images in knee of three-dimensional isotropic T_2 -weighted turbo spin echo MRI versus two-dimensional fast spin echo T_2 -weighted sequences for evaluation of posterior cruciate ligament injury

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Objective: To compare image quality between three-dimensional volume isotropic turbo spin echo acquisition (3D VISTA) with the posterior cruciate ligament (PCL) view and two-dimensional (2D) fast spin echo (FSE) for evaluation of PCL injury.

Methods: This retrospective study included 60 patients with clinical suspicion of PCL injury who underwent both 2D FSE and 3D VISTA of the knee between January 2015 and December 2015. The diagnostic performance of each oblique coronal view and the combined images was evaluated for sensitivity, specificity and accuracy for diagnosing a PCL tear. The arthroscopically confirmed diagnoses were used as the reference standard. Data were analyzed using the McNemar test.

Results: The mean contrast-to-noise ratio was significantly higher for 3D VISTA than for 2D FSE. The two

imaging modalities did not differ significantly in anatomical identification ability, with the exception of margin sharpness, which was inferior for 3D VISTA with Reader 2 ($p = 0.038$). When we classified the diagnoses of PCL injury as normal or abnormal, there were no significant differences in sensitivity, specificity or accuracy between the PCL view of 3D VISTA and 2D FSE images ($p > 0.05$).

Conclusion: 3D VISTA had a superior contrast-to-noise ratio than 2D FSE and similar image quality in the evaluation of the PCL. The PCL view of 3D VISTA has the same diagnostic ability as 2D FSE in the diagnosis of PCL injury and can thus replace 2D FSE.

Advances in knowledge: The oblique coronal view 3D VISTA MRI has similar diagnostic ability to 2D FSE in the diagnosis of PCL injury, and therefore 3D VISTA image can replace 2D FSE.

INTRODUCTION

Injury of the posterior cruciate ligament (PCL) is less common than injury of the anterior cruciate ligament (ACL), and it is difficult to diagnose clinically.^{1–3} PCL tears can result in posterior subluxation of the tibia and can require surgical intervention in severe cases.^{4–6} Park et al¹ reported that addition of the oblique coronal scan to the routine orthogonal imaging plane provides good anatomical evaluation of the PCL and improved diagnostic performance. The oblique coronal scan is obtained in the plane parallel to the line between the femoral and tibial insertion sites of the PCL (*i.e.* the PCL view). However, to realize the advantages of the PCL view, additional imaging sequences must be performed, and the additional oblique

plane imaging requires extra scan time. Three-dimensional (3D) isotropic images can be a solution to this problem. 3D MRI techniques acquire multiplanar reformatted images and reduce acquisition time by obtaining the same kinds of sequences in different anatomical planes.^{7–9} The usefulness of 3D MRI in the evaluation of the musculoskeletal system, including joint imaging, remains controversial.^{10,11} In evaluation of the ACL, Park et al¹² reported that the diagnostic performance of the additional ACL view on 3D isotropic turbo spin echo T_2 weighted MR [volume isotropic turbo spin echo acquisition MR (3D VISTA MR)] is comparable to that of two-dimensional (2D) fast spin echo (FSE) T_2 weighted MR (T2WI) in the diagnosis of ACL tears. No comparative studies have evaluated the diagnostic

efficacy of additional PCL views in 3D VISTA MR and 2D FSE T2WI for the diagnosis of PCL injury. We investigated whether the image quality and diagnostic performance of 3D VISTA MR with the PCL view is comparable to that of 2D T2WI for evaluation of the PCL.

METHODS AND MATERIALS

Case selection

Kangbuk Samsung hospital's institutional ethics review board approved this study, and the requirement for informed consent was waived because of the retrospective study design.

Of the patients who visited our hospital for various complaints of the knee joint between January 2015 and December 2015, 202 patients who consecutively underwent both 3D VISTA MR and 2D FSE T2WI with the PCL view were included in this retrospective study. We have taken these methods routinely in the musculoskeletal section as 3D VISTA MR is a commonly used imaging method. Clinical indications for knee MRI were joint pain and impaired mobility with various clinical suspicions, such as ligament injury, meniscal tear or osteoarthritis. Exclusion criteria were a history of knee joint surgery (ten cases), tumours of the bone (one case) and infection of the knee joint (one case). We also excluded 130 cases in which the patients did not undergo arthroscopy. Therefore, a total of 60 patients were included. The study participants included 24 females and 36 males (mean age: 44 ± 16 years, range: 17–74 years).

Arthroscopic diagnosis

The reference standards for diagnosis were based on the arthroscopic findings.

An orthopaedic surgeon with fellowship training in knee joint surgery and 33 years of experience performed all arthroscopic procedures and managements. The included surgical indications

were cruciate ligament injury, meniscal injury and cartilage injury. The mean interval between MRI and arthroscopy was 36 ± 48 days (range: 1–51 days). Probing was carried out through anterolateral and anteromedial portals, and distraction of the ligament structures was used to investigate the internal pathology of the knee joint. During the arthroscopic procedure, the surgeon examined the continuity of the ligament and the degree of swelling of the PCL. A normal PCL was diagnosed as the presence of intact fibres from the tibial to the femoral attachment.

MR parameters

All MR acquisition was performed with a 3.0-T MRI scanner (Achieva®; Philips Medical Systems, Best, Netherlands), and the receiver coil was an eight-channel coil dedicated for the knee joint. Detailed MR sequences and imaging parameters are summarized in Table 1. Oblique coronal views dedicated for the PCL (PCL view) were obtained in the plane parallel to the line between the femoral and tibial insertion sites of the PCL based on conventional sagittal T2WIs (Figure 1). To acquire 3D VISTA MR, 3D T2WI FSE images with a reconstruction voxel size of $0.5 \times 0.5 \times 0.5$ mm were obtained. We acquired the 3D isotropic sequence using an FSE 3D non-selective method, which uses short, non-volume selective FSE refocusing pulses. This technique has shorter echo spacing to prevent chemical shift artefacts, a driven-equilibrium radiofrequency pulse and an asymmetric FSE profile order.¹² Technologists at the hospital's radiology department reformatted the sagittal images acquired from 3D VISTA into oblique coronal images with the use of software (extended MR workspace, Philips Medical Systems). The images were reformatted with the same slice thickness and the same angle of the PCL view as the 2D FSE T2WI, without the interslice gap.¹²

Image analysis

First, a region of interest (ROI) was delineated within the midportion of the PCL to measure the 3D VISTA PCL view and 2D FSE T2WI PCL view signals. Two musculoskeletal

Table 1. MR parameters

Imaging parameter	Coro T_1 FSE	Coro FS T_2 FSE	Sag FS PD FSE	Sag T_2 FSE	PCL view Coro T_2 FSE	VISTA
TR (ms)	600–900	3500–4500	3500–4500	3500–4500	2500–3300	1500
TE (ms)	10–50	70–90	30–40	50–100	50–80	280–330
Flip angle (°)	90	90	90	90	90	90
Matrix size (pixels)	350×350	460×300	300×230	350×300	450×300	270×270
Field of view (cm)	16	16	16	16	14	16
Slice thickness (mm)	3	3	3	3	2	0.5
Interslice gap (mm)	0.3	0.3	0.3	0.3	0	0
Bandwidth (kHz)	270	253	256	239	217	520
Echo train length	6	14	12	14	15	85
Signal average	1	1	1	1	1	1
Scan time (min:s)	2:40	3:00	2:30	2:45	1:45	3:20

ACL, anterior cruciate ligament; Coro, coronal; FS, fat saturation; FSE, fast spin echo; PCL, posterior cruciate ligament; PD, proton density; Sag, sagittal; TE, echo time; TR, repetition time; VISTA, volume isotropic turbo spin echo acquisition.

Figure 1. (a) Sagittal T_2 weighted image [repetition time/echo time (TR/TE), 4200/70] showing the technique for obtaining the oblique coronal series [posterior cruciate ligament (PCL) views]. PCL views were acquired with 2-mm slice thickness parallel to the ligament insertion site on the tibia and femur (lines in a). (b, c) The same patient as in (a). A 53-year-old female with knee pain after a slip down. The PCL view of the two-dimensional fast spin echo (TR/TE, 2500/80, b) and the PCL view image reformatted from the three-dimensional volume isotropic turbo spin echo acquisition (TR/TE, 1500/320, c) showing the PCL (arrows). Regions of interest were placed within the PCL (large circles), joint space fluid (middle circles) and air of superolateral portion of the knee joint (small circles).

radiologists with 16 and 10 years of experience performed the measurements by consensus. The mean diameter of the ROI was 2 mm (minimum: 1.3 mm; maximum: 2.5 mm; Figure 1). The signal from the fluid of the joint space was measured with a 2-mm ROI, and the noise was measured with a 2-mm ROI that was superomedial to the soft tissue of the knee joint. We determined the signal-to-noise ratio (SNR) with the following equation: $SNR = \text{signal of the PCL or joint fluid} / \text{standard deviation of the background noise}$. We calculated the contrast-to-noise ratio (CNR; the difference between the SNRs for the two tissues) with the following equation: $CNR = SNR \text{ of fluid} - SNR \text{ of PCL}$.

Second, we determined the anatomical identification score of the PCL for the 3D VISTA and 2D T2WI PCL views. Initially, two radiologists evaluated the 3D VISTA PCL views independently, and then, 2 weeks later, they evaluated the 2D T2WI PCL views in the same manner. We determined the anatomical identification scores based on discrimination ability for the entire length and width of the PCL on each PCL view. The sharpness of the margin of the PCL was graded with a four-point scale: 0, poor; 1, fair; 2, good; and 3, excellent; Figures 2 and 3.¹³ The entire length score assessed how well the reader could perform longitudinal evaluation from the femur to the tibial ends. The entire length score was graded with a four-point scale as follows:

Figure 2. Normal posterior cruciate ligament (PCL). A 53-year-old male with knee pain without trauma. (a) The PCL view of two-dimensional fast spin echo [repetition time/echo time (TR/TE), 2500/80] showed excellent visualization of the ligament [arrows, >75% of the entire PCL length (Score 3), >75% of the entire width of the PCL (Score 3) and excellent demarcation of the PCL from adjacent soft tissue (Score 3)]. Total anatomical identification score was 9. (b) The PCL view reformatted from three-dimensional volume isotropic turbo spin echo acquisition (TR/TE, 1500/280) showed excellent visualization of the PCL [>75% of the entire length (Score 3), >75% of the entire width of the PCL (Score 3) and excellent demarcation of the PCL from adjacent soft tissue (Score 3)]. Total anatomical identification score was 9.

Figure 3. Normal posterior cruciate ligament (PCL). A 72-year-old female with knee pain without trauma. (a) The PCL view of two-dimensional fast spin echo [repetition time/echo time (TR/TE), 2500/80] had good but not excellent visualization of the ligament [arrows, >75% of the entire PCL length (Score 3), <75% of the entire width of the PCL (Score 2) and good but not excellent demarcation of the PCL from adjacent soft tissue (Score 2)]. Total anatomical identification score was 7. (b) The PCL view reformatted from three-dimensional volume isotropic turbo spin echo acquisition (TR/TE, 1500/300) showed excellent visualization of the PCL [>75% of the entire length (Score 3), >75% of the entire width of the PCL (Score 3) and excellent demarcation of the PCL from adjacent soft tissue (Score 3)]. Total anatomical identification score was 9.

0, <25% of the entire length of the PCL could be evaluated on a single image of the PCL view; 1, 25–50% could be evaluated; 2, 50–75% could be evaluated; and 3, 75% could be evaluated.^{13,14} The entire width score assessed how well the reader could perform transverse evaluation of the PCL from the medial to the lateral border of the ligament.¹³ Margin sharpness was also graded with a four-point scale, where 0 indicated poor demarcation of the PCL from adjacent soft tissue; 1, fair demarcation; 2, good demarcation; and 3, excellent demarcation.¹⁴

Third, to compare the diagnostic performance of the 3D VISTA PCL view and 2D T2WI PCL view, each radiologist interpreted the

individual 3D VISTA image and 2D T2WI independently. Initially, the readers independently diagnosed whether PCL injury was present using the 3D VISTA PCL view only. Neither reader had access to information from radiological reports or the patient's clinical history. 2 weeks later, they made the same diagnoses based on the 2D T2WI PCL view only. After another 2 weeks, they made diagnoses using the orthogonal MR (coronal T_1 weighted FSE and sagittal T2WI, not the PCL view). In the same manner, they made diagnoses using the 3D VISTA PCL view with orthogonal MR and 2D T2WI with orthogonal MR, with a 2-week interval. The PCL was considered normal if continuous low signal intensity was observed in the ligament (Figures 2 and 3).^{1,15} We considered the

Figure 4. Partial tear of the posterior cruciate ligament (PCL). A 57-year-old female with knee pain without trauma. (a) The PCL view of two-dimensional fast spin echo [repetition time/echo time (TR/TE), 2500/80] showed a focal bright signal in the midportion of the PCL (arrow) but intact fibre continuity. (b) The PCL view reformatted from three-dimensional volume isotropic turbo spin echo acquisition (TR/TE, 1500/320) showed a focal bright signal in the midportion of the PCL (arrow) but intact fibre continuity. Partial tear of the PCL was confirmed *via* arthroscopy.

Table 2. Signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR)

Images		Mean	Standard deviation	<i>p</i> -value
SNR of ligament	3D VISTA	9.80	3.97	<0.001
	2D FSE	11.04	2.24	
SNR of fluid	3D VISTA	176.47	46.65	<0.001
	2D FSE	137.45	27.00	
CNR	3D VISTA	169.56	70.70	<0.001
	2D FSE	50.47	13.94	

2D FSE, two-dimensional fast spin echo; 3D VISTA, three-dimensional volume isotropic turbo spin echo acquisition.

PCL to have a partial tear if a wavy contour or a thin but continuous low signal was observed, or if there was a focal or diffuse high signal within the PCL itself without elongation (Figure 4).¹ The PCL was considered to have a complete tear if the ligament showed definite discontinuity.

Statistical analysis

We used paired *t*-tests to compare the SNR and CNR of the PCL between the 3D VISTA and 2D FSE images. Interobserver agreement for anatomical identification between the two musculoskeletal radiologists was assessed with intraclass correlation coefficients (ICCs). Interpretation of the ICC values was as follows: excellent agreement, >0.75; fair-to-good agreement, 0.40–0.75; and poor agreement, <0.40.¹⁶ Anatomical identification of the PCL on 3D VISTA and 2D FSE as graded by the two observers was compared with Wilcoxon signed-rank tests. Interreader agreement of diagnostic performance was analyzed with kappa statistics. We interpreted the kappa values as follows: poor, $k < 0.1$; slight agreement, $0.1 \leq k \leq 0.2$; fair agreement, $0.2 < k \leq 0.4$; moderate agreement, $0.4 < k \leq 0.6$; substantial agreement, $0.6 < k \leq 0.8$; and nearly perfect agreement, $0.8 < k \leq 1$.¹⁷ The diagnostic performance of 3D VISTA, 2D FSE and the combination of these imaging modalities with orthogonal images in the differentiation of normal and abnormal results for diagnosis of PCL tear was evaluated in terms of sensitivity, specificity and accuracy. The surgically confirmed diagnoses were used as the reference standard. McNemar tests were used for analyses of the clinical significance of the values. Statistical analyses were with PASW® software v. 18.0 (IBM Corp., New York, NY; formerly SPSS Inc., Chicago, IL). *p*-values ≤ 0.05 were considered statistically significant.

RESULTS

Although the mean SNR of the PCL was lower for 3D VISTA than for 2D FSE, the mean CNR was significantly higher for 3D VISTA than was for 2D FSE (Table 2, both $p < 0.001$). The ICCs for the anatomical identification scores of the PCL on 3D VISTA and 2D FSE ranged from 0.629 to 0.892, indicating fair-to-good or excellent interreader agreement (Table 3). Table 4 summarizes the mean scores for anatomical ligament identification of the PCL. The two imaging modalities did not differ significantly in anatomical identification ability, with the exception of inferior identification ability of 3D VISTA for margin sharpness by Reader 2 ($p = 0.038$, Table 4). The agreement between the two readers for the diagnostic performance of the various imaging methods ranged from substantial to nearly perfect agreement ($0.615 < k < 0.914$, Table 5). When we classified the diagnoses of PCL injury as normal and abnormal, there were no significant differences in sensitivity, specificity or accuracy between 3D VISTA and 2D FSE images ($p > 0.05$, Table 6).

DISCUSSION

3D isotropic MRI techniques have less partial volume averaging artefacts because they use continuous thin slice sections and make good delineation of small and complex anatomical details.^{10,18} The 3D isotropic images also allow for 3D reformatting in arbitrarily chosen orientations.¹⁸ Although 3D sequences based on gradient-echo imaging generally have poor SNR and CNR, 3D VISTA has been shown to have superior tissue contrast in knee joint evaluation.^{18,19} Similar 3D FSE techniques of other vendors are CUBE (GE Healthcare, Waukesha, WI) and SPACE (Siemens Medical Solutions, Erlangen, Germany) techniques.^{7,20} 3D VISTA provides high spatial resolution and good T_2 contrast

Table 3. Intraclass correlation coefficients (ICCs) of two radiologists for scores on anatomical identification of the posterior cruciate ligament

Images	Evaluation of entire length ^a (a)	Evaluation of entire width ^a (b)	Evaluation of margin sharpness (c)	Total (a + b + c)
3D VISTA	0.717 (0.568–0.821)	0.812 (0.704–0.883)	0.764 (0.633–0.852)	0.838 (0.743–0.900)
2D FSE	0.798 (0.684–0.874)	0.619 (0.435–0.754)	0.892 (0.826–0.934)	0.808 (0.699–0.881)

2D FSE, two-dimensional fast spin echo; 3D VISTA, three-dimensional volume isotropic turbo spin echo acquisition.

Numbers in parentheses are 95% confidence intervals.

ICCs were rated as follows: poor, <0.40; fair to good, 0.40 < κ $\leq$ 0.75; excellent, >0.75.

^aDiscrimination ability through the entire length.

Table 4. Mean scores for anatomical identification of the posterior cruciate ligament (PCL) on three-dimensional volume isotropic turbo spin echo acquisition (3D VISTA) and two-dimensional (2D) T_2 fast spin echo (FSE)

Images	Evaluation of entire length ^a (a)	Evaluation of entire width ^a (b)	Evaluation of margin sharpness (c)	Total (a + b + c)
3D VISTA	2.55 ± 0.59/2.52 ± 0.60 (1–3)	2.52 ± 0.60/2.52 ± 0.60 (1–3)	2.53 ± 0.65/2.52 ± 0.60 (1–3)	7.60 ± 1.49/7.55 ± 1.42 (3–9)
2D FSE	2.60 ± 0.56/2.65 ± 0.52 (1–3)	2.57 ± 0.53/2.60 ± 0.49 (1–3)	2.60 ± 0.56/2.63 ± 0.55 (1–3)	7.77 ± 1.27/7.88 ± 1.12 (3–9)
<i>p</i> -value	0.317/0.074	0.297/0.297	0.285/0.038	0.162/0.038

Values are mean ± standard deviation, and displayed as Reader 1/Reader 2.

Data in parentheses show the range of values.

p-values are from comparisons of the orthogonal views and PCL views.

^aDiscrimination ability through the entire length.

with a reasonable scan time by using long echo train length and parallel imaging techniques.¹⁸ Previous studies have reported that 3D VISTA is comparable or superior to 2D FSE for the evaluation of the nerve root in the cervical spine and that it has high sensitivity and specificity in the evaluation of meniscal tears and the ACL.^{18,20,21} Park et al¹³ reported that the SNRs and CNRs are higher for 3D VISTA than for 2D FSE in their study on the anterior talofibular ligament (ATFL) of the ankle joint. In the current study, the mean SNR of the PCL was lower on 3D VISTA than on 2D FSE, whereas the mean CNR was higher for 3D VISTA than for 2D FSE. These differences may be explained in part by the different anatomical locations (ATFL vs PCL) assessed in the two studies.¹³ However, a different study reported lower SNR of the ligament structure on 3D FSE, which is consistent with our results.²²

The two imaging modalities allowed for similar anatomical identification of the PCL in terms of the ability to visualize the entire length, entire width and margin sharpness. However, 3D VISTA led to inferior identification ability for margin sharpness by Reader 2 (Table 4). Park et al¹³ reported that 3D VISTA images have relatively poor image sharpness, resulting in an inferior margin sharpness score. However, in our study, one radiologist (HJP) was able to evaluate margin sharpness similarly between the two imaging methods ($p = 0.285$). We suggest that the difference in image quality for margin sharpness between these two imaging methods is not as prominent for the PCL as it is for the ACL or other ligament structures, such as the ATFL or calcaneofibular ligament. The interreader agreement was substantial and equivalent for 3D VISTA ($k = 0.760$) and 2D FSE ($k = 0.615$). Furthermore, when each image was combined

with orthogonal images, the interreader agreements for both sequences (*i.e.* orthogonal view and 3D VISTA PCL view, or orthogonal view and 2D FSE) were nearly perfect ($k = 0.914$ and 0.839 , respectively; Table 5) for the diagnosis of PCL injury.

Diagnostic performance did not differ between 3D VISTA and 2D FSE, even when each was combined with the orthogonal view, in the discrimination of a PCL tear from normal ligament. The usefulness of the oblique coronal view in diagnosing PCL injury had already been studied.¹ Park et al¹² reported that the oblique view on 3D VISTA has comparable diagnostic ability to 2D FSE in the diagnosis of ACL injury.²³ Although 3D reformatted images have indistinct margins, and therefore decreased spatial resolution, this problem did not occur in our evaluation of PCL injury.²⁴ We can attribute these results to the fact that the diagnosis of PCL injury is based on whether or not the PCL has its own continuity and whether or not there is homogeneous low signal intensity of the ligament, which explains why inferior sharpness does not affect diagnostic performance. Thus, we suggest that 3D VISTA can replace 2D FSE in the evaluation of PCL injury without sacrificing diagnostic ability.

With regard to scan time, Lim et al²⁵ reported that 3D VISTA fat suppression imaging time was 8 minutes shorter than 2D images. However, they compared diagnostic performances between 3D VISTA fat suppression and conventional T2WI with orthogonal plane. In the scan time benefit of oblique images, 3D VISTA only has a time benefit over 2D FSE when the orthogonal images and the oblique view are replaced with the 3D reformatted image.¹² We suggest that total scan time can be reduced

Table 5. Interreader agreement for diagnostic performance

Images	Kappa value	95% confidence interval	<i>p</i> -value
3D VISTA PCL view	0.760	0.538–0.983	<0.001
2D FSE PCL view	0.615	0.346–0.885	<0.001
Orthogonal view + 3D VISTA PCL view	0.914	0.747–1.000	<0.001
Orthogonal view + 2D FSE PCL view	0.839	0.622–1.000	<0.001

2D FSE, two-dimensional fast spin echo; 3D VISTA, three-dimensional volume isotropic turbo spin echo acquisition; PCL, posterior cruciate ligament. Kappa values are shown with 95% confidence intervals.

Kappa value interpretation: poor, $k < 0.1$; slight agreement, $0.1 \leq k \leq 0.2$; fair agreement, $0.2 < k \leq 0.4$; moderate agreement, $0.4 < k \leq 0.6$; substantial agreement, $0.6 < k \leq 0.8$; and nearly perfect agreement, $0.8 < k \leq 1$.

Table 6. Diagnostic performance (sensitivity, specificity and accuracy) of three-dimensional volume isotropic turbo spin echo acquisition (3D VISTA), two-dimensional fast spin echo (2D FSE) and combined with orthogonal images in the differentiation between normal and abnormal for diagnosis of posterior cruciate ligament (PCL) tears

Images	Sensitivity (%)		Specificity (%)		Accuracy (%)	
	Observer 1	Observer 2	Observer 1	Observer 2	Observer 1	Observer 2
3D VISTA PCL view	85.7 (06/07)	85.7 (06/07)	90.6 (48/53)	94.3 (50/53)	90.0 (54/60)	93.3 (56/60)
2D FSE PCL view	100 (07/07)	85.7 (06/07)	90.6 (48/53)	100 (53/53)	91.7 (55/60)	98.3 (59/60)
<i>p</i> -value	1.000	1.000	1.000	0.250	1.000	0.250
Orthogonal view + 3D VISTA PCL view	100 (07/07)	85.7 (06/07)	100 (53/53)	100 (53/53)	100 (60/60)	98.3 (59/60)
Orthogonal view + 2D FSE PCL view	100 (07/07)	85.7 (06/07)	98.1 (52/53)	100 (53/53)	98.3 (59/60)	98.3 (59/60)
<i>p</i> -value	1.000	1.000	1.000	1.000	1.000	1.000

Numbers in parentheses are the numbers of patients used to calculate the percentages.

if the oblique sagittal view and oblique coronal view of the ACL are replaced with the 3D image and the PCL view because it had already been reported that the diagnostic performance of additional ACL views on 3D VISTA is comparable to that of 2D FSE images in the evaluation of the ACL.¹² The scan time of the oblique sagittal view and oblique coronal view of the ACL in our hospital is about 4 min, whereas the scan time for the PCL view of 2D FSE is 1 min and 45 s. As the scan time for 3D VISTA is 3 min and 20 s (not including reformatting time on the work station), the scan time for 2D FSE is about 42% lower than that of 3D VISTA, if the orthogonal views are not included in the reformatted sequences.

This study had some limitations. First, the study had a small number of positive cases. Only 7 of 60 cases (12%) included in this study had a positive diagnosis (partial or complete PCL tear). Second, although the imaging parameters were masked when the reader evaluated the images, a completely blinded comparison was

difficult because the reader may have been able to determine which imaging method was used based on margin sharpness since the margins were not as sharp for the 3D reformatted images as for the 2D FSE images. Third, the recognition of the case among the separate evaluation can be a bias because the same case was read three times with a time interval of only 2 weeks between each evaluation. Fourth, this work is based on 3.0-T MRI, and this is not widely available. As far as we know, many reports on 3D VISTA are based on higher field strength MRI, and our study is also based on 3.0-T MR. 3D VISTA needs multichannelled knee dedicated coil which is not prepared for our lower field strength MR, and therefore we might need much more scanning time if the 3D VISTA image had to be performed on 1.5-T MRI.

In conclusion, 3D VISTA had a superior CNR than 2D FSE and similar image quality in the evaluation of the PCL. 3D VISTA has the same diagnostic ability as 2D FSE in the diagnosis of PCL injury and can replace 2D FSE.

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