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ORIGINAL RESEARCH ARTICLE

Detection of Knee Effusion by Ultrasonography

ABSTRACT

Hong BY, Lim SH, Cho YR, Kim HW, Ko YJ, Han SH, Lee JI: Detection of knee effusion by ultrasonography. Am J Phys Med Rehabil 2010;89:715–721.

Objectives: The purpose of this study was to assess which scan view was sensitive in detecting knee effusion by ultrasonography while infusing normal saline in cadaveric specimens.

Design: Intraarticular injection of normal saline with contrast dye was done in increments (5, 10, 15, and 20 ml) into the knee joint of eight fresh cadavers. After infusion of each amount, sonographic images were obtained with five different scans: medial, midline, and lateral on longitudinal scans, and medial and lateral on transverse scans. When 20 ml had been injected, the knee was flexed at 30 degrees and serial images were taken.

Results: After infusion of 10 ml, effusion of more than 2 mm depth with ultrasonography was most frequently seen in lateral transverse scans (14/14), and the next most frequent view was a lateral longitudinal scan (11/14). After knee flexion, the amount of effusion was increased on medial and middle longitudinal scans and was decreased on transverse scans.

Conclusions: For detecting knee effusion by ultrasonography, lateral transverse and longitudinal scans were the most sensitive in the knee extension posture. With knee flexion at 30 degrees, effusion was more readily detected on the medial and midline longitudinal scans than with knee extension.

Key Words: Ultrasonography, Knee, Cadaver, Intraarticular Injections

Ultrasonographic examination is widely used for detecting various musculoskeletal disorders.[1–3] Ultrasonography is noninvasive, suitable for the visualization of superficial structures, and reproducible; moreover, it generally costs less than magnetic resonance imaging.[4,5] A comparative study between magnetic resonance imaging and ultrasonography evaluation revealed a significant correlation between the two techniques for evaluating the morphologic changes in patients with knee osteoarthritis.[6]

Knee effusion is a common sign of knee pathology and is significantly associated with synovitis and aggravation of pain.[7] In a cadaveric study, a volume of 1 ml of fluid was visible with magnetic resonance imaging in the sagittal plane.[8] However, generally, knee effusions of less than 6–8 ml cannot be appreciated clinically.[9] Ultrasonography is superior to clinical examination in the detection

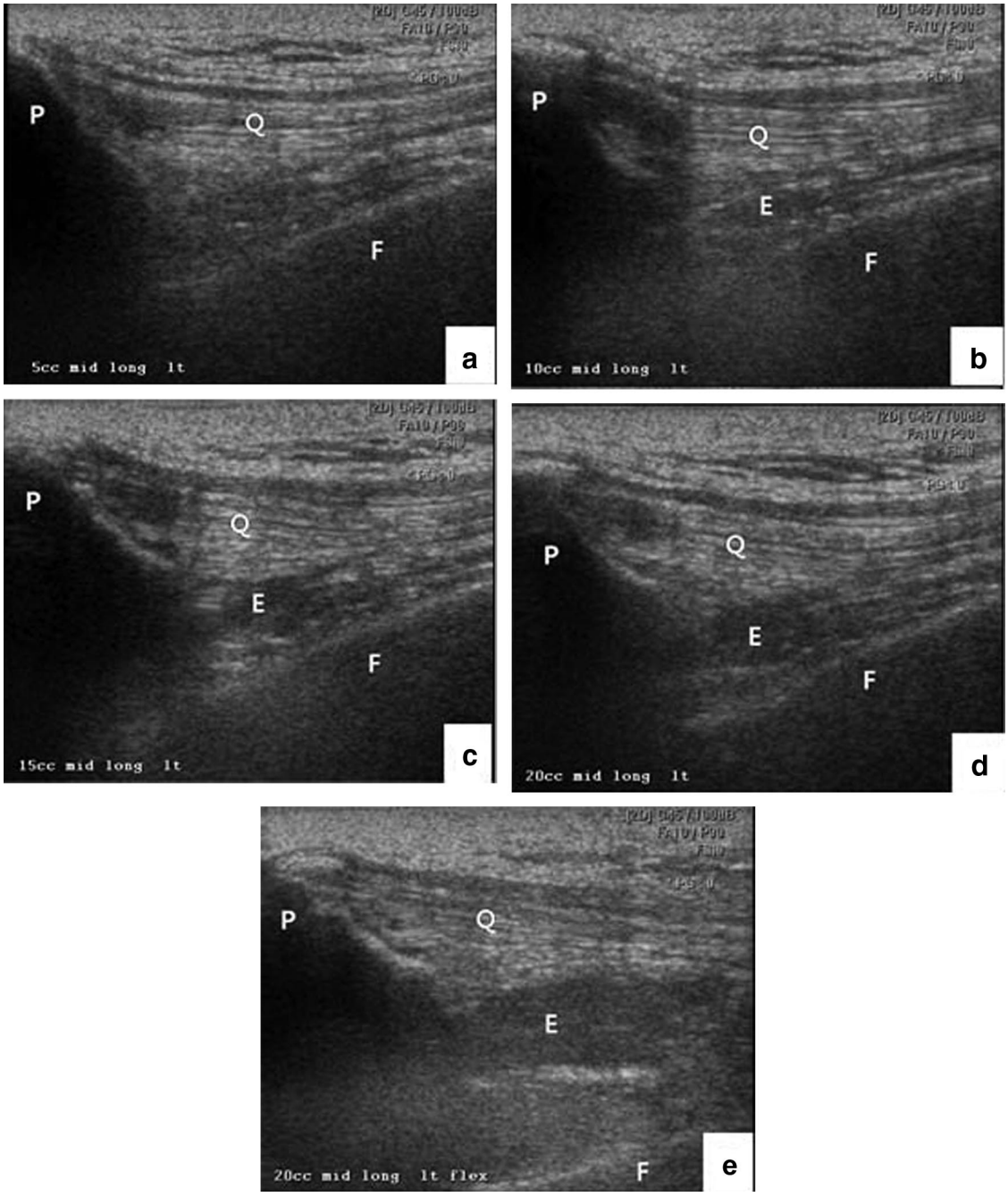

FIGURE 1 *Midline longitudinal scan views with infusion in increments. Sonographic measurements of the depth of the effusion were done with knee extension after infusion of* (a) *5 ml,* (b) *10 ml,* (c) *15 ml,* (d) *20 ml and then,* (e) *with knee flexion after infusion of 20 ml. P, patella; Q, quadriceps tendon; F, femur; E, effusion.*

and localization of knee joint effusion[5,10] and correlates well with arthroscopic findings.[5]

The sonographic criteria for the presence of knee effusion are not always consistent among researchers. Knee effusion has been defined as fluid accumulation with a depth of 2 mm[6,11,12] and 4 mm[7,13] with the transducer oriented longitudinally with knee extension. Some authors defined the presence of effusion with the knee flexed at 30 degrees as distention larger than 2 mm at the midline or medial and lateral on longitudinal and transverse scans.[10,14] The sensitivity of sonographic examination in detecting effusion with respect to magnetic resonance imaging diagnosis was 79.1% when the presence of effusion was defined as fluid accumulation exceeding 2 mm.[15] A small amount of fluid is physiologic and is usually less than 2 mm in depth on a longitudinal ultrasonographic scan.[11,12,16] Longitudinal imaging is recommended for the detection of fluid, and the smallest collection in the knee joints can be demonstrated only at the level of the medial and lateral parapatellar recesses, because these are the most dependent portions of the knee while the patient is supine.[9,11,16]

The purposes of this study were (1) to identify which scan view was sensitive in detecting knee effusion while infusing normal saline under ultrasonography guidance in cadaveric specimens, and (2) to assess the clinical relevance of current cutoff values, a depth of 2 mm or more and 4 mm or more, for the diagnosis of knee joint effusion by ultrasonography.

METHODS

Participants

We screened 16 knees from 8 different fresh cadavers using ultrasonography, and if fluids were present in the suprapatellar pouch, we aspirated to eliminate any fluid before the study. We excluded two knee specimens from one cadaver because very thin contracted knee allowed only poor visualization by ultrasonography on one side, and the other side had fluid leakage out of the joint, confirmed by fluoroscopy. Fourteen knee specimens from seven different fresh cadavers (3 men and 4 women) were obtained. The age range was 62–88 yrs (mean, 78 yrs). The mean height of the cadavers was 160 cm (range, 150–170 cm).

Protocol

We prepared saline mixtures in 10-ml syringes by combining 9 ml of normal saline and 1 ml of Gastrografin (Bayer Schering Pharma AG, Madrid, España). With the knees in extension and 15 degrees of external rotation, we inserted a 21-gauge needle into the middle lateral aspect of the knee joint under ultrasonography guidance and attached the 10-ml syringe to the needle via a three-way

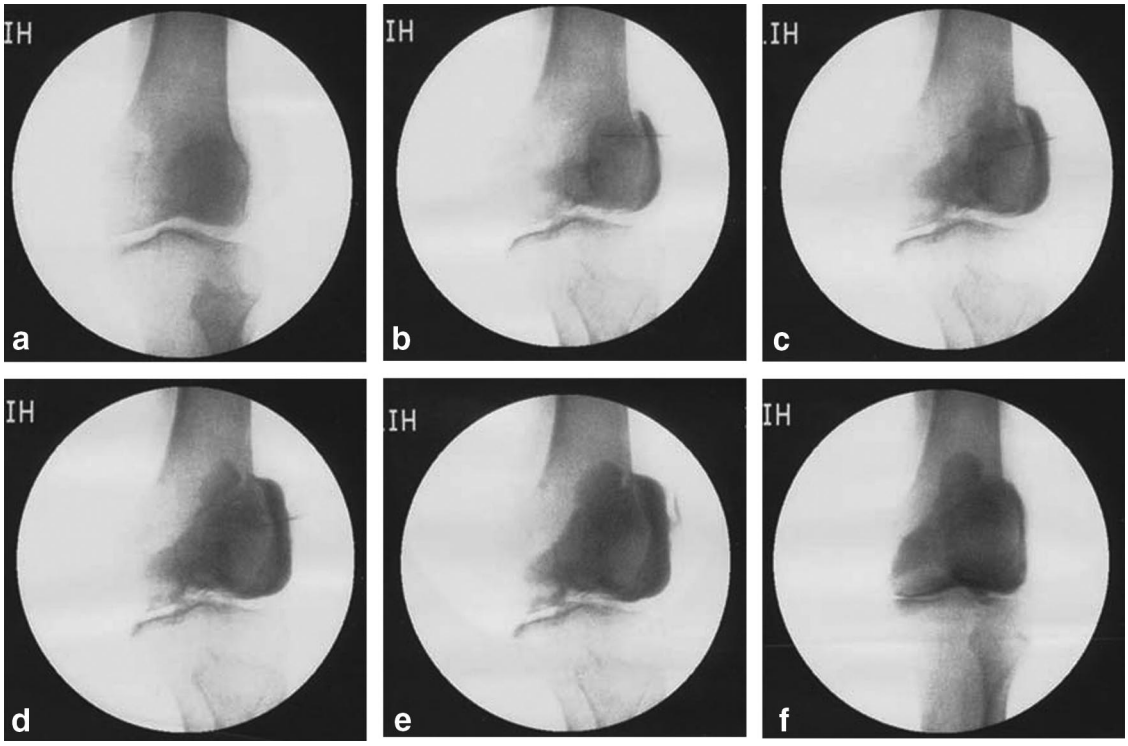

FIGURE 2 *Fluoroscopic images of the knee. Fluoroscopic images were taken serially with knee extension, (*a*) baseline, (*b*) after infusion of 5 ml, (*c*) after infusion of 10 ml, (*d*) after infusion of 15 ml, (*e*) after infusion of 20 ml, and (*f*) with knee flexed after infusion of 20 ml.*

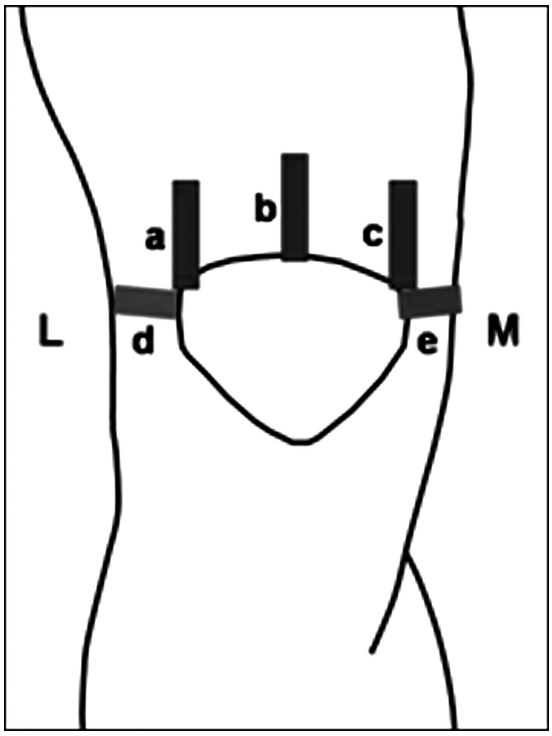

FIGURE 3 *Schematic drawing illustrates five different transducer positions. L, lateral; M, Medial; a, lateral longitudinal; b, midline longitudinal; c, medial longitudinal; d, lateral transverse; e, medial transverse.*

stopcock (Insung medical Co., Seoul, Korea). Normal saline and contrast dye were injected into the joint space in increments (5, 10, 15, and 20 ml). After each injection, we recorded fluoroscopic images to rule out rupture of the knee joint and obtained sonographic images with five different scans: medial, midline, and lateral on the longitudinal scans and medial and lateral on the transverse scans (Figs. 1a–e and 2a–f).[12] Each scan was named according to the relative location of the transducer along the superior border of the patella (Fig. 3). The transducer was placed parallel to the long axis of the leg serially, medial to lateral, in the longitudinal scans, and for the transverse scans, it was placed perpendicular to the long axis of the leg on either side of the upper part of the patella. When 20 ml had been injected, the knee was flexed at 30 degrees and serial images were taken.

Measurement of Knee Effusion

Ultrasonography was performed by one of the authors with an 8- to 10-MHz linear array transducer (Accuvix XQ, Medison Co., Ltd, Seoul, Korea). Observing ultrasonography, we compressed the suprapatellar pouch gently using a transducer and while slowly removing the pressure of the transducer, we took images when the most effusion was confirmed by ultrasonography. In this manner, we made an effort to minimize the pressure on the suprapatellar recess while taking images by ultrasonography. We defined joint effusion as a hypoechoic or an anechoic area in the suprapatellar recess, between the quadriceps tendon and prefemoral fat.[9–11,13,15] Effusion was measured by one clinician at the maximal depth observed in the scans.

Statistical Analysis

Descriptive statistics and means were used to describe the features of the data. We transformed raw data into a binary number system to examine the presence of effusion based on two different definitions, $\geq$2 mm and $\geq$4 mm. Statistical analyses were performed using the standard software package, SPSS 11.5 for Windows. The paired Student's t test was used to compare the variables between knee extension and flexion. We also estimated the relationship between the amount of infusion and sonographic depth of effusion by linear regression analysis. P values <0.05 were deemed to indicate statistical significance.

RESULTS

Figure 4 and Table 1 present the mean depth of effusion in five different scans. Measured depth of knee effusion was significantly increased as the amount of infusion was increased in all scan groups ($P < 0.05$). After knee flexion, the mean depth of knee effusion was significantly increased in medial and midline longitudinal scans, $P = 0.000$, $P = 0.001$, respectively, and it was significantly decreased in medial and lateral transverse scans, $P = 0.000$, $P = 0.001$, respectively. No significant change was observed in lateral longitudinal scans ($P = 0.402$).

The presence of knee effusion on ultrasonography was demonstrated using two predefined cutoff points (2 and 4 mm). Ultrasonography knee effusion at a depth of 2 mm or greater was most frequently seen on the lateral transverse scan (11/14; 78.6%) after infusion of 5 ml of saline mixture (Table 2). After infusion of 10 ml, effusion was present in 14/14 (100%) and 8/14 (57.1%) knees on the lateral and medial transverse scans, respectively, and in 11/14 (78.6%), 4/14 (28.6%), and 1/14 (7.1%) knees in the lateral, midline, and medial longitudinal scans, respectively. After infusion of 20 ml, knee effusion was detected on all scanning views (100%), except the medial longitudinal scan (11/14; 78.6%; Table 2). With a cutoff value of 4 mm, 2/14 (14.3%) knees showed effusion on the lateral transverse scan after 5 ml of infusion (Table 3). After infusion of 10 ml, effusion was present in 10/14 (71.4%) knees on the lateral transverse scan, 7/14 (50%), 2/14 (14.2%), 2/14 (14.2%), 0/14 (0%)

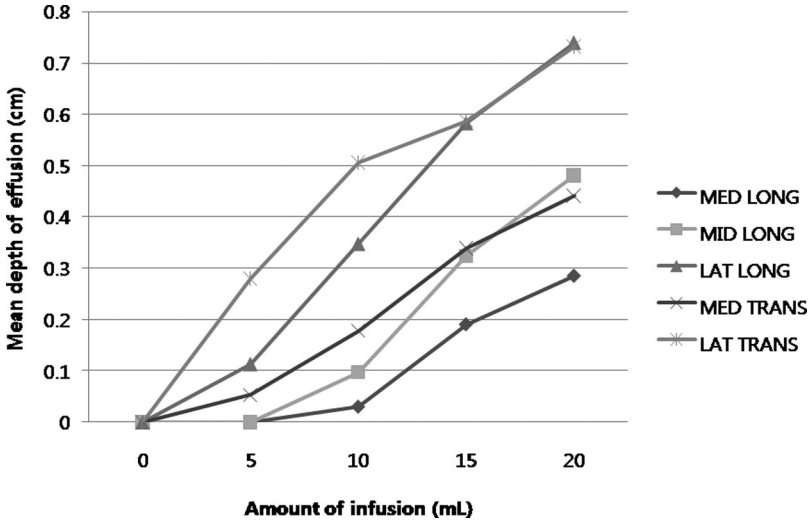

FIGURE 4 *Mean depth of effusion on ultrasonography in each scan with increasing amounts of infusion. MED LONG, medial longitudinal; MID LONG, midline longitudinal; LAT LONG, lateral longitudinal; MED TRANS, medial transverse; LAT TRANS, lateral transverse.*

on the lateral longitudinal, medial transverse, midline, and the medial longitudinal scans, respectively. After a 20-ml infusion, knee effusion was present in 13/14 (92.9%) knees on the lateral transverse and longitudinal scans, and 9/14 (64.3%), 8/14(57.1%), and 3/14 (21.4%) knees on the medial transverse, midline, and medial longitudinal scans, respectively.

DISCUSSION

The smallest amount of fluid detectable by ultrasonography in the knee has been reported to be 7–10 ml in a cadaver study.[17] In that study, the authors used transverse images of the lateral and superior quadricipital pouches to identify effusion. They did not clearly state the detectable fluid, but this might have been less than 2 mm. In our study, after infusion of 5 ml, 78.6% of knees showed an effusion depth of 2 mm or more in the lateral transverse scan; however, less than 25% of knee effusion was detected in other scan views. With the infusion of 10 ml, effusion was present in all knees on lateral transverse scans. Thus, it seems that the sonographic detection threshold for knee effusion was likely between 5 and 10 ml, similar to that reported in a previous study.[9,17]

With an effusion criterion of 4 mm depth, the detection rate of knee effusion by ultrasonography was considerably lower. Only 14.3% of knees showed effusion after 5-ml infusion, and 71.4% of knees showed effusion after infusing 10 ml of fluid on the lateral transverse scan. With longitudinal scans, 50% or less was detected. The exact amount of physiologic fluid in the knee joint is not known, and it is not clear how much amount of knee effusion has clinical significance. However, to meet the criterion of 4-mm depth, more than 10 ml of fluid has to be in the joint. This quantity might be somewhat larger than expected for physiologic conditions.

TABLE 1 Mean depth of effusion by ultrasonography according to the amount of infusion and knee posture

Knee Posture	Extended					Flexed at 30 Degrees
Amount of infusion (ml)	0	5	10	15	20	20
MED LONG (cm)	0	0.00	0.03	0.19	0.29	0.53*
MID LONG (cm)	0	0.00	0.10	0.32	0.48	0.64*
LAT LONG (cm)	0	0.11	0.35	0.58	0.74	0.77
MED TRANS (cm)	0	0.05	0.18	0.34	0.44	0.32*
LAT TRANS (cm)	0	0.28	0.51	0.59	0.73	0.39*

*$P < 0.01$ by paired t test, knee extension *vs*. knee flexion after infusion of 20 ml.

MED LONG, medial longitudinal; MID LONG, midline longitudinal; LAT LONG, lateral longitudinal; MED TRANS, medial transverse; LAT TRANS, lateral transverse.

TABLE 2 Presence of knee effusion according to the cutoff value of 2 mm depth

Amount of infusion (ml)	Count (n) Percentage (%)	MED LONG		MID LONG		LAT LONG		MED TRANS		LAT TRANS	
		<2 mm	≧2 mm	<2 mm	≧2 mm	<2 mm	≧2 mm	<2 mm	≧2 mm	<2 mm	≧2 mm
5	Count	14	0	14	0	11	3	12	2	3	11
	Percentage	100.0	0	100.0	0	78.6	21.4	85.7	14.3	21.4	78.6
10	Count	13	1	10	4	3	11	6	8	0	14
	Percentage	92.9	7.1	71.4	28.6	21.4	78.6	42.9	57.1	0	100.0
15	Count	7	7	4	10	0	14	2	12	0	14
	Percentage	50.0	50.0	28.6	71.4	0	100.0	14.3	85.7	0	100.0
20	Count	3	11	0	14	0	14	0	14	0	14
	Percentage	21.4	78.6	0	100.0	0	100.0	0	100.0	0	100.0
Total	Count	37	19	28	28	14	42	20	36	3	53
	Percentage	66.1	33.9	50.0	50.0	25.0	75.0	35.7	64.3	5.4	94.6

MED LONG, medial longitudinal; MID LONG, midline longitudinal; LAT LONG, lateral longitudinal; MED TRANS, medial transverse; LAT TRANS, lateral transverse.

The medial and lateral parapatellar recesses are the most dependent recesses of the knee while the patient is supine.[9] We found that knee effusion was most commonly located in the lateral compartment with small volumes, and as fluid volume increased, it appeared in the medial compartment; ultrasonographic and fluoroscopic images showed similar tendencies. This might be caused by the injection technique, a mid-lateral approach, or by the slightly externally rotated knee posture. This finding is also consistent with another study. Kane[10] stated that knee effusion was more commonly found in the lateral compartment than in the medial compartment. Among five different scans in the current study, the most sensitive transducer location for finding small amounts of knee joint effusion was the lateral transverse scan, followed by lateral longitudinal and medial transverse scans. In the supine position, the lateral parapatellar recess is more dependent than the medial recess and, thus, lateral transverse and longitudinal scans will be helpful in detecting a small amount of fluid in the knee joint. Although we studied the knee in 30 degrees flexion only after the infusion of 20 ml of fluid, more joint fluid was recognized under this condition on midline and medial longitudinal scans, whereas the depth of effusion significantly decreased in transverse scans. This suggests that shifts of fluid occur toward the center of the joint with knee flexion. It might be partly because of internal rotation of the knee while flexing the joints. However, significant decrease of amount in medial transverse scan could not be explained by posture. We did not flex the knee with a small amount of effusion, because it might redistribute the fluid during the study or alter the needle placement. We thought this could have an influence on the accuracy of further infu-

TABLE 3 Presence of knee effusion according to the cutoff value of 4 mm depth

Amount of infusion (ml)	Count (n) Percentage (%)	MED LONG		MID LONG		LAT LONG		MED TRANS		LAT TRANS	
		<4 mm	≧4 mm	<4 mm	≧4 mm	<4 mm	≧4 mm	<4 mm	≧4 mm	<4 mm	≧4 mm
5	Count	14	0	14	0	13	1	14	0	12	2
	Percentage	100.0	0	100.0	0	92.9	7.1	100.0	0	85.7	14.3
10	Count	14	0	12	2	7	7	12	2	4	10
	Percentage	100.0	0	85.7	14.3	50.0	50.0	85.7	14.3	28.6	71.4
15	Count	13	1	10	4	1	13	9	5	1	13
	Percentage	92.9	7.1	71.4	28.6	7.1	92.9	64.3	35.7	7.1	92.9
20	Count	11	3	6	8	1	13	5	9	1	13
	Percentage	78.6	21.4	42.9	57.1	7.1	92.9	35.7	64.3	7.1	92.9
Total	Count	52	4	42	14	22	34	40	16	18	38
	Percentage	92.9	7.1	75.0	25.0	39.3	60.7	71.4	28.6	32.1	67.9

MED LONG, medial longitudinal; MID LONG, midline longitudinal; LAT LONG, lateral longitudinal; MED TRANS, medial transverse; LAT TRANS, lateral transverse.

sion and sonographic depth of effusion. There may be a pattern of distribution with knee flexion, but, we are not able to know further details in our current study, except the shift of fluid toward the center with large amount of effusion. Clinically, we could suggest that flexing the knee might be better at detecting effusion in midline and medial longitudinal scans. However, there is a limitation to generalize the distribution pattern of knee effusion according to knee posture because we studied only with 20 ml of effusion. To identify and generalize the specific pattern of redistribution, further study might be needed with various amounts of effusion in living subjects.

Study Limitations

Because this study was conducted with cadaveric specimens, it has some limitations. There may be differences in joint stiffness and the pattern of fluid distribution between cadavers and living patients. The number of studied knees was also small, which limits the generalization of our results. Thus, further study is needed to confirm the pattern of fluid distribution in the clinical setting.

CONCLUSIONS

With the knee extended, the lateral transverse view was the most sensitive for detecting small knee effusions. And the sensitivity for ultrasonography to detect knee effusion is between 5 and 10 ml, based on the observation that within this range the fluid becomes visible in all knees in at least one scan view (typically the lateral transverse scan). With a large effusion of 20 ml, knee flexion causes a redistribution of fluid within the knee, toward the center of the joints. It is possible that flexing the knee may increase the visibility of a small effusion on the medial and midline longitudinal scans. The depth of effusion detected by ultrasonography can significantly differ according to the subject's posture. Thus, it is important that the studied posture is clearly stated in ultrasonography research. Additionally, our study results suggest that a cutoff value of 4 mm is too high for the definition of knee effusion and that 2 mm is a more reasonable cutoff value.

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