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Does ultrasound guidance improve the outcomes of arthrocentesis and corticosteroid injection of the knee?

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Objective: The present randomized controlled trial compared arthrocentesis of the effusive knee followed by corticosteroid injection performed by the conventional anatomic landmark palpation-guided technique to the same procedure performed with ultrasound (US) needle guidance.

Methods: Sixty-four palpably effusive knees were randomized to (i) palpation-guided arthrocentesis with a conventional 20-mL syringe (22 knees), (ii) US-guided arthrocentesis with a 25-mL reciprocating procedure device (RPD) mechanical aspirating syringe (22 knees), or (iii) US-guided arthrocentesis with a 60-mL automatic aspirating syringe (20 knees). The one-needle two-syringe technique was used. Outcome measures included patient pain by the Visual Analogue Scale (VAS) for pain (0–10 cm), the proportion of diagnostic samples, synovial fluid volume yield, complications, and therapeutic outcome at 2 weeks.

Results: Sonographic guidance resulted in 48% less procedural pan (VAS; palpation-guided: 5.8 3.0 cm, US-guided: 3.0 2.8 cm, $p < 0.001$), 183% increased aspirated synovial fluid volumes (palpation-guided: 12 10 mL, US-guided: 34 25 mL, $p < 0.0001$), and improved outcomes at 2 weeks (VAS; palpation-guided: 2.8 2.4 cm, US-guided: 1.5 1.9 cm, p ¼ 0.034). Outcomes of sonographic guidance with the mechanical syringe and automatic syringe were comparable in all outcome measures.

Conclusions: US-guided arthrocentesis and injection of the knee are superior to anatomic landmark palpation-guided arthrocentesis, resulting in significantly less procedural pain, improved arthrocentesis success, greater synovial fluid yield, more complete joint decompression, and improved clinical outcomes.

Arthrocentesis is useful for the diagnosis of septic or inflammatory arthritis, and is the basic underlying procedure for intra-articular therapy, including therapeutic arthrocentesis, needle lavage, and intra-articular injection (1–8). Complete arthrocentesis before injection of corticosteroidorhyaluronanconfirmsthediagnosis, reducesthe possibility of superimposed infection, reduces patient pain, and improves the response to the injected drug (5–12). Despite the importance of arthrocentesis to the diagnosis and management of arthritis, arthrocentesis with conventional methods can be unsuccessful, painful, and unnecessarily traumatic (11–21).

Ultrasound (US) is increasingly used to detect synovial effusions and to guide the needle for arthrocentesis and intra-articular injections (21–30). However, it remains controversial whether US guidance is beneficial for diagnostic arthrocentesis, therapeutic arthrocentesis, or intra-articular injections (21–33). Certain recent studies have found that US guidance does not improve the outcomes of arthrocentesis or intra-articular injections, although these negative results may have been due to technique and selection of syringe device rather than to a primary failure of US guidance (21, 30, 33, 34).

We hypothesized that US-guided arthrocentesis of the kneefollowedbycorticosteroidinjectionwouldbesuperior to the conventional technique. The present randomized controlled study examined the outcomes of arthrocentesis and injection of the effusive knee using conventional methods compared to US-guided aspiration and injection.

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Methods and materials

Subjects

This project was in compliance with the Helsinki Declaration and approved by the institutional review board (IRB), and was registered at ClinicalTrials.gov (Clinical Trial Identifier NCT00651625). Inclusion criteria included: (i) palpable symptomatic effusion of the knee with suprapatellar distention, (ii) indications for therapeutic-diagnostic arthrocentesis, (iii) indication for corticosteroid injection, and (iv) formal consent of the patient to undergo the procedure and participate in the research. Sixty-four palpably effusive knees were randomized to (i) palpation-guided arthrocentesis with a conventional 20-mL syringe (22 knees), (ii) US-guided arthrocentesis with a 25-mL reciprocating procedure device (RPD) mechanical syringe (22 knees), or (iii) US-guided arthrocentesis with a 60-mL automatic syringe (20 knees). Forty-three of the subjects had rheumatoid arthritis and 21 osteoarthritis of the knee randomized and evenly distributed between the treatment groups. Age and gender were similar between the treatment groups ($p > 0.4$ for all).

Needle introduction technique forUS-guided arthrocentesis

The straight leg lateral suprapatellar bursa (superiolateral) approach was used to insert the needle and perform arthrocentesis (Figures 1–4) (13–15). Prior to the procedure, the presence of suprapatellar bursal distention was confirmed by physical examination. The knee was placed in the extended position, and the US probe placed transversely over the quadriceps tendon to image the distended suprapatellar bursa (Figure 1).

The one-needle multiple-syringe technique was used, where (i) one needle is used for anaesthesia, arthrocentesis, and intra-articular injection; (ii) a first syringe or syringes are used to anaesthetize the synovial membrane and completely aspirate effusion, and (iii) a final syringe is used to inject the intra-articular therapy (19). For the US-guided procedures, a 25-gauge 1.5-inch needle (305783 BD Eclipse Safety Needle; BD, Franklin Lakes, NJ, USA; www.bd.com) was mounted on a 5-mL RPD mechanical syringe (3-mL RPD procedure syringe; AVANCA Medical Devices, Inc, Albuquerque, NM, USA; www.avancamedical.com) filled with 5 mL of 1% lidocaine (Xylocaine® 1%, AstraZeneca Pharmaceuticals LP, Wilmington, DE, USA). Using a 25-gauge needle on the mechanical syringe, 3 mL of lidocaine was used to first anaesthetize the skin, subcutaneous tissues, and synovial membrane. The needle was then extracted and inactivated, and rotated off of the mechanical syringe. Subsequently, an 18-gauge 1.5-inch needle was placed on the 5-mL mechanical syringe, and introduced into the knee, expelling the remaining 2 mL of lidocaine into the synovial membrane, and then the lateral parapatellar recess of the suprapatellar bursa was penetrated and 5 mL of synovial fluid aspirated into the mechanical syringe (Figures 1 and 2). The 5-mL mechanical syringe was then rotated off of the intraarticular needle and the needle left in place.

Arthrocentesis with the RPD mechanical syringe

The mechanical syringe for arthrocentesis was a 25-mL RPD mechanical syringe (AVANCA Medical Devices,

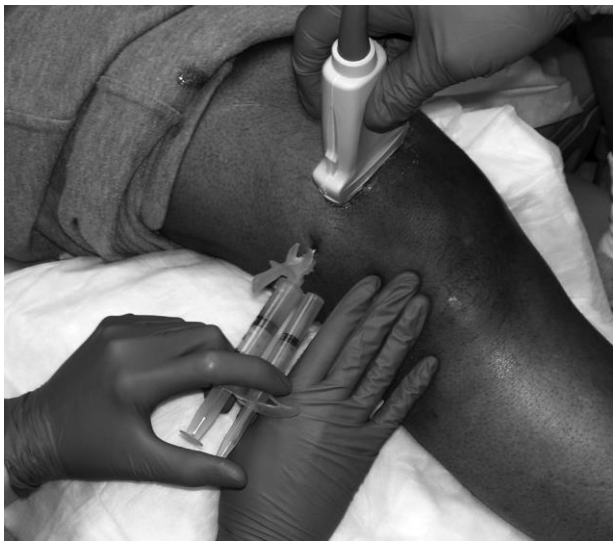

Figure 1. Needle introduction and anaesthesia with a 5-mL mechanical syringe. This photograph demonstrates an RPD mechanical syringe being used in a one-handed fashion after surface anaesthesia for introduction of the 18-gauge 1.5-inch arthrocentesis needle. The larger plunger is depressed with the thumb for injection and the smaller plunger is depressed with the thumb for aspiration. The free hand is used to steady the patient, feel the surface anatomy, or operate other devices. After filling the 5-mL mechanical syringe, syringe exchange is performed, placing either the 25-mL RPD mechanical syringe or the 60-mL vacuum syringe on the indwelling intra-articular needle.

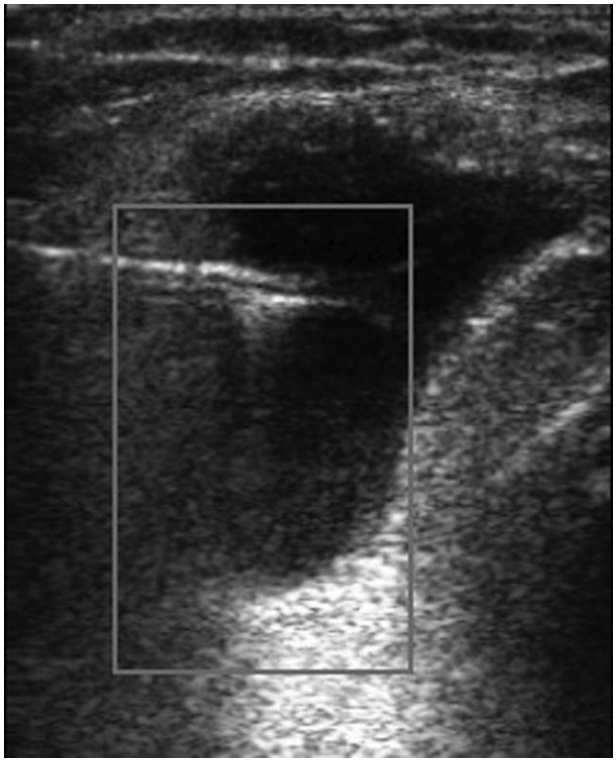

Figure 2. Ultrasound-guided needle introduction. This sonographic image shows the needle introduced into the effusion of the suprapatellar bursa from the superiolateral portal with a straight positioning.

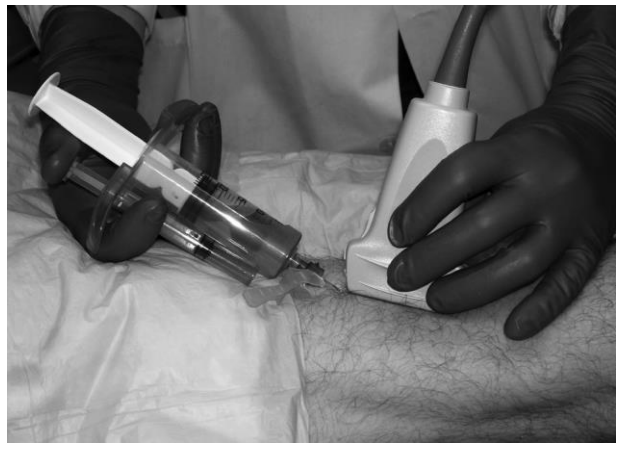

Figure 3. Arthrocentesis with a 25-mL mechanical syringe. This photograph demonstrates the mechanical syringe being used in a one-handed fashion for aspiration and drainage of a knee effusion. The 25-mL device has been attached to the introduced intra-articular needle as shown in Figures 1 and 2. The larger plunger is depressed with the thumb for injection and to clear the needle, and the smaller plunger is depressed with the thumb for aspiration. As shown here, the smaller plunger is depressed gently for continuous aspiration. The free hand is used to feel the anatomy, steady the syringe, apply pressure to the effusion, or to operate an ultrasound transducer.

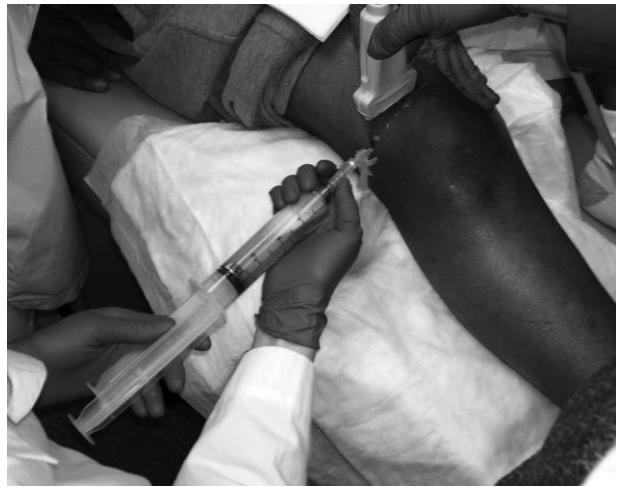

Figure 4. Arthrocentesis with a 60-mL automatic syringe. This photograph demonstrates a 60-mL automatic aspirating syringe being used in a one-handed fashion for aspiration and drainage of a knee effusion. The flow valve is opened with the thumb, and then the syringe is passively held as it performs large volume arthrocentesis.

Inc). The mechanical syringe is formed around the core of a conventional syringe barrel and plunger but has a parallel accessory plunger and an accessory barrel to control the motion of the accessory plunger (Figure 3). The two plungers are linked mechanically by a pulley in an opposing fashion, resulting in a set of reciprocating plungers. Thus, when the aspiration plunger is depressed with the thumb, the syringe aspirates, and when the injection plunger is depressed with the thumb, the syringe injects. This permits the index and middle fingers to remain in one position during both aspiration and

injection, while the thumb only needs to move in a horizontal plane to the alternative plunger to change the direction of aspiration or injection. This device permits greater control when used with sonography and easy detection of small amounts of synovial fluid that flash back into the barrel confirming true intra-articular positioning (21, 35–40).

For more complete arthrocentesis, a 25-mL mechanical syringe was first cycled to break the bond of the plunger stopper with the barrel, and the air was then expelled. The mechanical syringe was then rotated on the indwelling needle (or the needle rotated on the syringe) and then the aspiration plunger was gently depressed. The mechanical syringe was then filled with 25 mL of synovial fluid while controlling the needle with US guidance. If the joint was not completely decompressed, the mechanical syringe was rotated off of the intra-articular needle, and the syringe emptied into a sterile specimen container. The mechanical syringe was then reattached and filled again as above. After the joint had been aspirated as completely as possible by sonography, the mechanical syringe was rotated off of the needle, and a 3-mL conventional syringe prefilled with 80 mg triamcinolone acetonide suspension [Kenalog® 40, Westwood-Squibb Pharmaceuticals, Inc (Bristol-Myers Squibb), New York, NY, USA] was rotated onto the intra-articular needle, and the treatment was injected. The needle was then extracted, and firm pressure applied to the puncture site.

Arthrocentesis with the automatic syringe

The automatic syringe consisted of a conventional 60-mL syringe (309653 60-mL Syringe, Luer-Lok™ Tip; BD) that was fitted with a sterile flow switch and locking plunger (AVANCA Medical Devices, Inc). To create a vacuum in the 60-mL syringe, the flow switch was closed, the plunger pulled back to the 60-mL mark and the plunger locking mechanism activated, fixing the plunger in the aspiration position (Figure 4). This 60-mL automatic syringe achieved a vacuum level of 650 Torr (mmHg).

The 60-mL automatic syringe was rotated onto the 18gauge indwelling intra-articular needle. The flow switch was then opened and synovial fluid began flowing automatically into the syringe (Figure 4). Movement of fluid could be observed in the transparent portion of the flow switch. The syringe was then filled automatically with up to 60 mL of fluid. If more fluid remained, the flow switch was closed, and the vacuum syringe and switch were rotated off of the indwelling needle. Then a second automatic syringe was attached and the flow switch opened and the process was repeated. After complete arthrocentesis (Figure 5), the automatic syringe was rotated off and corticosteroid injected as above.

Conventional landmark palpation-guided arthrocentesis

The palpation-guided injection procedure was also performed in a standardized manner using the one-needle

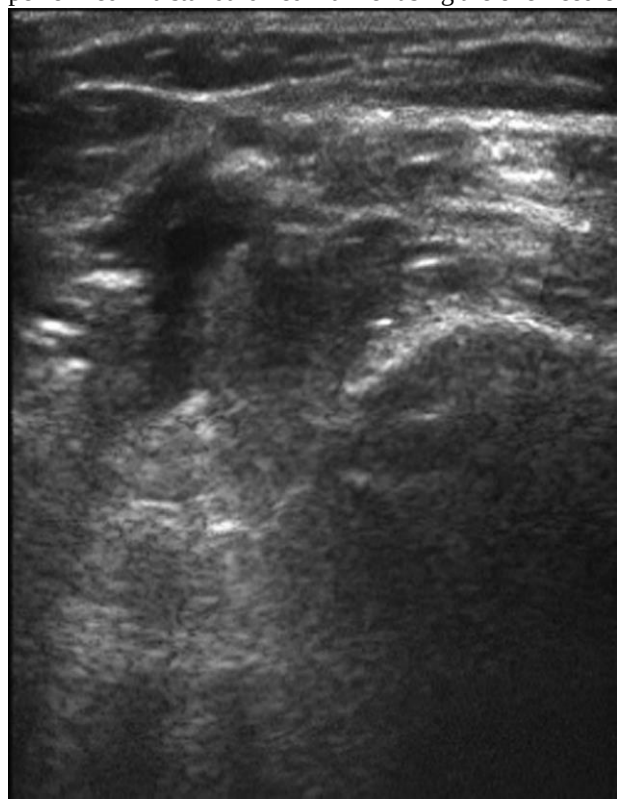

Figure 5. Complete arthrocentesis. This sonographic image shows collapse of the suprapatellar bursa after full aspiration and injection with corticosteroid.

two-syringe technique as above but using conventional syringes without sonographic guidance. A 5-mL or 20-mL conventional syringe (309604; BD), as appropriate, was operated with two hands and was used for all palpationguided procedures.

Outcome measures

Aspirated fluid volume was quantified in millilitres.

Adequate diagnostic fluid was defined as 2.5 mL (0.5 mL

Table 1. Clinical outcomes of US-guided arthrocentesis.

for crystal examination, 1 mL for culture, and 1 mL for cell counts). Patient pain was measured with the standardized and validated 0–10 cm Visual Analogue Scale (VAS) for pain, where 0 cm ¼ no pain and 10 cm ¼ unbearable pain (21, 34–43). Significant pain was defined as a VAS score 5 cm (19). Pain by VAS was determined prior to the procedure (baseline pain), during arthrocentesis (procedural pain), and 2 weeks

postprocedure (pain at primary outcome). The pain scores at the primary outcome were obtained by an observed blinded to treatment arm. Two weeks has been demonstrated as the outcome measurement time most likely to detect maximum clinical effect of injected corticosteroid (44–47); thus, the 2-week observation was considered the primary outcome measure (21).

Statistical analysis

Data were entered into Excel and analysed in SAS. The primary comparison was between anatomic landmark palpation-guided procedures and pooled US-guided procedures, and the secondary comparison between the automatic syringe and the RPD mechanical syringe. Measurement data were compared post-hoc with the Student t-test, and categorical data with Fisher's exact test with corrections for multiple comparisons. A power calculation was made using preliminary data at this level, where α¼ 0.0001, power ¼ 0.9, and allocation ratio ¼ 1.0 indicated that n ¼ 10 in each group would provide statistical power at the $p < 0.001$ level and n ¼ 20 in each group at the $p < 0.0001$ level.

Results

Other than procedural pain, there were no complications in any of the treatment groups. US-guided arthrocentesis was superior in all outcome measures (Table 1). Direct clinical comparisons between the two US-guided techniques are shown in Table 2. Both techniques permitted

	Conventional palpation-guided arthrocentesis	US-guided arthrocentesis	Percentage difference	95% CI	p-value
Number of subjects	22	42			
Pre-procedure baseline pain (10 cm VAS), cm				15 to þ9.8	0.68
Procedural pain (10 cm VAS), cm	7.75.868	7.53.031	348	74 to – 22	0.001
Significant procedural pain (10 cm VAS 5 cm), %	(15/22) 1.83.0	(13/42) 2.02.8	54	169 to – 83	0.004 0.003
Percentage of successful diagnostic aspiration (2.5 mL)	82 (18/22)	100 (42/42)	22 þ183	5 to 47	0.0001
Mean aspirated synovial fluid, mL				110 to	0.034
Pain at outcome (2 weeks) (10 cm VAS), cm	2.812 102.4	1.534 251.9	þ46	276 88 to – 5	

CI, Confidence interval.

Values given as number, percentage, or mean standard deviation.

Table 2. Clinical outcomes of aspirating syringes.

	60-mL automatic syringe	25-mL mechanical syringe	Percentage difference	95% CI	p-value
Number of subjects	22	20			
Pre-procedure baseline pain (10 cm VAS), cm	7.5 1.8	7.4 2.2	1	18 to þ15	0.87
Procedural pain (10 cm VAS), cm	2.932 (7/22) 3.1	3.130 (6/20) 2.5	þ76	5487 toto	0.82
Significant procedural pain (10 cm VAS 5 cm), %				þþ6879	0.87
Mean aspirated synovial fluid, mL	9 (2/22)35 23	340 (0/20) 27l		3067547	0.90 0.35
Inability to clear needle, %			3100		0.87
Pain at outcome (2 weeks) (10 cm VAS), cm	1.5 1.8	1.6 2.1	þ7	tototo	
				þþþ884291	

CI, Confidence interval.

Values given as number, percentage, or mean standard deviation.

facile large volume body fluid aspiration, and were equivalent in procedural pain, aspirated fluid volume, and pain outcome. In two cases with the automatic syringe, the 18-gauge needle became clogged with a loculated effusion, and could not be cleared without disengaging the locking plunger. By contrast, when the needle became clogged on the mechanical syringe, it could be easily cleared by depressing the injection plunger and then aspiration could be resumed by gently depressing the aspiration plunger.

Discussion

The present study compared US-guided arthrocentesis to conventional anatomic landmark palpation-guided arthrocentesis and demonstrated improved patient outcomes with US guidance, including significantly less procedural pain, greater aspirated fluid volume, a greater percentage of successful diagnostic arthrocentesis, and improved response to corticosteroid injection (Tables 1 and 2). Thus, the present study demonstrates that USguided arthrocentesis of the effusive knee is superior to conventional anatomic landmark palpation-guided arthrocentesis.

A number of prior studies have examined the use of US guidance for arthrocentesis and/or intra-articular injection specifically of the knee. Im et al demonstrated that US increased the accuracy of needle placement for successful intra-articular injection into the knee (48). Kane et al, Delaunoy et al, and Ike et al have demonstrated that US can detect small effusions in the knee, and may assist with more successful arthrocentesis (22, 23, 27). Wiler et al reported that US-guided arthrocentesis of the knee did not significantly increase fluid yield (30). Cunnington et al, in a large study of inflammatory arthritis that included knees, found that US significantly improved intraarticular accuracy but did not improve injection outcomes (33). Thus, the prior literature is inconsistent regarding the role of US guidance in arthrocentesis and injection of the knee.

The present study demonstrates that US guidance significantly reduces the procedural pain of arthrocentesis (Table 1), confirming prior reports (30). Although the causes of reduced procedural pain are uncertain, better control and direction of the needle tip away from painsensitive structures into the target structure are likely explanations (18, 21, 34–41). Im et al demonstrated that US increased the accuracy of needle placement, and this increased accuracy into the joint and away from painsensitive structures could result in less pain (48). Reduction of procedural pain has also been demonstrated with better control of the needle (33–41). An alternative explanation is that the cooling effect of US gel, the pressure from the US transducer, and the patient observing the sonographic image may have a distracting effect at the neurocognitive level, significantly reducing pain and anxiety (17, 49, 50).

The present study also demonstrated a significant increase in successful diagnostic arthrocentesis and a significant increase in aspirated fluid volume, unlike the previous reports of arthrocentesis of the knee (Table 2). The increased synovial fluid yield in the present study compared to Wiler et al (30) is probably the result of different patient populations; the Wiler et al study was performed in an emergency department where the knees were extremely symptomatic and massively and acutely distended, whereas the present study was performed in a rheumatology clinic with more chronic effusions with typically less acute distention (30). This is confirmed by comparing the fluid yields of the Wiler et al study in which the US group yielded 32% more fluid than the present study, indicating more massive acute effusions presenting a much larger target for the needle and, thus, less need for US guidance (9–11, 30).

The current study demonstrated that US-guided arthrocentesis and intra-articular injection of the knee improved outcomes compared to the conventional anatomic landmark palpation-guided technique (Table 1). By contrast, the recent Cunnington et al study demonstrated no improvement in intra-articular injection outcomes with US guidance (33). The reasons for these differing results are almost certainly due to the diverging methods of the two studies. In contrast to the Cunnington et al study, which used direct one-step injection, the present study used a two-step one-needle two-syringe technique including complete US-guided arthrocentesis prior to injecting the intra-articular medication (33). Arthrocentesis is important, as aspirating synovial fluid into the syringe further confirms true intra-articular positioning of the needle tip, and complete decompression of the joint by arthrocentesis prior to injection increases effective intra-articular concentrations of the injected drug, improving clinical outcomes (9–11). Thus, the present study further emphasizes the need for complete arthrocentesis and decompression of the joint prior to injection of intra-articular medications.

The negative results of the Cunnington et al study could also have been due to differences in the injected medications. In the Cunnington et al study, the iodinated radio-opaque contrast agent iohexol was injected into the joints along with corticosteroid (33). Iodinated contrast agents, although useful to determine intra-articular accuracy, are highly irritating to cartilage and synovial membrane and are known to induce synovitis, which might obscure the beneficial effects of intra-articular corticosteroids and thus would have a negative effect on the US-guidance group relative to the palpation group (46, 51–54). The Cunnington et al study also used lower amounts of triamcinolone acetonide, which would tend to

converge the results of the US-guided and palpationguided groups, as was in fact observed (33, 44–47, 55).

Conventional arthrocentesis is usually carried out by one operator using a conventional syringe with two hands. However, it is difficult to control and operate a conventional syringe with one hand while operating the US transducer with the other hand and, as Cunnington et al and others have demonstrated, results in less improvement than would be expected (16, 33, 36, 37, 41, 56). By contrast, the present study combined US with highly controlled mechanical aspirating syringes that permitted one-handed operation with improved needle control (16, 36, 37, 41, 56). With a mechanical aspirating syringe, US-guided arthrocentesis can be performed with two operators (as shown in Figures 1 and 4), one holding the probe and the other aspirating the synovial fluid; or it can be performed with one operator operating the US probe with one hand and the aspirating syringe with the other hand (as shown in Figure 3). Thus, the use of highly controlled one-handed aspirating syringes that provide better needle control and accuracy with US may have also contributed to better outcomes in the US-guided group (16, 21, 34, 36, 37, 41, 56).

In summary, US-guided arthrocentesis of the knee is superior to anatomic landmark palpation-guided arthrocentesis, resulting in significantly less procedural pain, a greater percentage of successful diagnostic arthrocenteses, greater synovial fluid yield, more complete joint decompression, and improved clinical outcomes.

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