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ORIGINAL ARTICLE

Extractable synovial fluid in inflammatory and non-inflammatory arthritis of the knee

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Abstract

Introduction/objectives We hypothesized that mechanical compression of the knee in rheumatoid arthritis (RA) would mobilize occult extractable fluid and improve arthrocentesis success.

Methods Sixty-seven consecutive knees with RA and 186 knees with OA and were included. Conventional arthrocentesis was performed and success and volume (milliliters) determined; the needle was left intraarticularly, and mechanical compression was applied with an elastomeric knee brace. Arthrocentesis was then resumed until fluid return ceased. Fluid was characterized as to volume and cell counts.

Results In the RA, knee mechanical compression decreased failed diagnostic arthrocentesis from 56.7% (38/67) to 26.9% (18/67) (− 47.4%, $p = 0.003$) and increased absolute arthrocentesis yield from 4.7 ± 10.3 ml to 9.8 ± 9.8 ml (108% increase, 95% CI − 8.5 < − 5.1 < − 1.7 $p = 0.0038$). Total extractable fluid yield was 96% greater in RA (9.8 ± 9.8 ml) than OA (5.0 ± 9.4 ml, $p = 0.0008$), and occult extractable fluid was 77% greater in RA than OA (RA 5.3 ± 8.7 ml, OA 3.0 ± 5.5 ml, $p = 0.046$). Large effusions versus small effusions in RA demonstrated increased neutrophils in synovial fluid ($p = 0.04$) but no difference in radiologic arthritis grade ($p = 0.87$). In contrast, large effusions versus small effusions in OA demonstrated no difference in neutrophils in synovial fluid ($p = 0.87$) but significant different radiologic arthritis grade ($p = 0.04$).

Conclusion Mechanical compression improves the success of diagnostic and therapeutic knee arthrocentesis in both RA and OA. Large effusions in RA are associated with increased neutrophil counts but not arthritis grade; in contrast, large effusions in OA are associated with more severe arthritis grades but not increased neutrophil counts.

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Key Points

- *Mechanical compression of the painful knee improves arthrocentesis success and fluid yield in both rheumatoid arthritis and osteoarthritis.*
- *The painful rheumatoid knee contains approximately 100% more fluid than the osteoarthritic knee.*
- *Large effusions in the osteoarthritic knee are characterized by higher grades of mechanical destruction but not increased neutrophil counts.*
- *In contrast, large effusions in the rheumatoid knee are characterized by higher synovial fluid neutrophil counts but not the grade of mechanical destruction, indicating different mechanisms of effusion formation in rheumatoid arthritis versus osteoarthritis.*

Keywords Arthrocentesis · Injections · Intraarticular · Knee · Quality

Introduction

Arthritis of the knee is often complicated by joint effusions that are aspirated to exclude infection, permit classification of synovial fluid, provide diagnosis, and therapeutically decompress the joint [1–5]. Meehan et al., Bhavsar et al., and others have recently demonstrated that mechanical compression of the knee improved arthrocentesis success and yield beyond conventional arthrocentesis by mobilizing occult extractable fluid [6–9]. In rheumatoid arthritis, the synovial membrane is typically hypertrophied and edematous, there are deep recesses between the synovial villi that potentially can trap fluid, and the synovial fluid contains far more cellular elements, all factors that may contribute to incomplete fluid extraction [1–5, 10–15]. It is presently unknown whether mechanical compression of the knee also provides greater arthrocentesis success in rheumatoid arthritis as has been shown previously in osteoarthritis [7–9].

We hypothesized that mechanical compression of the painful knee in rheumatoid arthritis would provide similar improved arthrocentesis success as in osteoarthritis and that rheumatoid arthritis would be associated with more extractable synovial fluid than osteoarthritis.

Materials and methods

The Quality Improvement program and data analysis was formalized in the Division of Rheumatology, Department of Internal Medicine, University of New Mexico Health Science Center; was approved by the institutional review board (IRB); and was in compliance with the Helsinki Declaration and subsequent revisions. This project assessed quality improvement of knee arthrocentesis in terms of overall success, outcome, and quality among individual patients who underwent arthrocentesis with and without constant compression applied by a compressive brace intended to remove the operator's hands from the operative field and prevent potential needlestick, yet still provide robust compression of the knee during arthrocentesis and injection procedures [7–9, 16]. The quality intervention was designed as a paired study in the same knee: that is, first conventional arthrocentesis was performed in an individual knee and quality and outcome measures were obtained, then immediately after conventional arthrocentesis, constant compression was applied to the same knee in the same individual, and quality measures were obtained once again. Three hundred consecutive painful knees were screened for this study. Only knees with symptomatic osteoarthritis or rheumatoid arthritis were included; thus, 47 knees with other diagnoses (crystal disease, spondyloarthritis, infectious arthritis, traumatic arthritis) were excluded. Knees that had received a corticosteroid injection less than 4 months prior to the study were excluded. One hundred and eighty-six consecutive painful knees with grades I–III osteoarthritis (OA) and 67 consecutive painful knees with rheumatoid arthritis (RA) were included. OA of the knee was classified as per Brandt et al., and RA was classified as per the American College of Rheumatology RA classification criteria [17, 18]. All knees were graded as to radiologic severity (grades 0 to 3) as has been previously described [17]. Inclusion criteria for the quality program for arthrocentesis and joint injection included the following: (1) painful symptomatic knee osteoarthritis or rheumatoid arthritis with the patient requesting a knee arthrocentesis and injection, (2) indications for therapeutic-diagnostic arthrocentesis and/or injection, (3) indication for corticosteroid injection, and (4) formal signed consent of the patient to undergo the procedure.

Arthrocentesis and joint injection technique

All the procedures were performed with a resident physician or rheumatology fellow under the direct "hands on" supervision of one highly experienced attending proceduralist. In all cases, the skin was first cleaned with chlorhexidine for antisepsis. Arthrocentesis was performed in a conventional manner, using the standard lateral approaches [19, 20]. The lateral portal was determined by palpation and marked with ink. The one-needle multiple-syringe technique was used where (1) one needle is placed for anesthesia, arthrocentesis, and intraarticular injection; (2) a first syringe or syringes are used to anesthetize the synovial membrane and completely aspirate effusion employing syringe exchanges if the effusion were large; and (3) a final syringe is used to inject the intraarticular therapy, in this case, a corticosteroid. A 22-gauge 2-in. needle

(4710007050-22 GX2" (0.7 × 50 mm), FINE-JECT, Henke Sass Wolf, Kettenstrasse 1 D-78532 Tuttlingen, Germany) was mounted on a 3-ml syringe (3 ml Luer Lok syringe, BD, 1 Becton Drive, Franklin Lakes, NJ 07417, website: http://www.bd.com) filled with 3 ml of 1% lidocaine (Xylocaine® 1%, AstraZeneca Pharmaceuticals LP, 1800 Concord Pike, P.O. Box 15437, Wilmington, DE, 19850-5437). Three milliliters of lidocaine was used to first anesthetize the skin, subcutaneous tissues, and synovial membrane as the 22-g needle was introduced through the skin into the lateral parapatellar recess of the suprapatellar bursa, and if there were no synovial fluid return, the needle was directed inferiorly under the patella into the patellofemoral joint toward the intercondylar notch. The knee was then compressed or "milked" by the operator's free hand, and a fully conventional arthrocentesis was performed. After the conventional arthrocentesis was performed and fluid yield was recorded, the intraarticular needle was left in the joint, an elastomeric knee brace (YooSoo Adjustable Knee brace, Shenzhen Shi Hai Xun Yun Wei Co.,Ltd. No.203, 69 Dong, Liyuan Xin Cun, Bantian Street, Longgang, 518000, Shenzhen, China, Amazon, https://www.amazon.com) modified so that the lateral suprapatellar bursa and patellofemoral joint could expand with fluid expressed due to constant compression from the brace on the medial and inferior knee and was placed on the knee (Fig. 1). The brace was tightened so that the patient felt considerable pressure, but the brace did not impede arterial flow in the leg. Placed this way, the brace applied constant compression without the use of human hands to the medial suprapatellar bursa and the synovial compartments of the medial and lateral inferior knee, collapsing these compartments, and forcing fluid to the lateral suprapatellar bursa and the patellofemoral joint where fluid could be accessed (Fig. 2). The syringe was then rotated off of the intraarticular needle, the needle was left in place in its intraarticular position, a 3-ml syringe was prefilled with 1 mg/kg triamcinolone acetonide suspension (maximum 80 mg) (Kenalog® 40, Westwood-Squibb Pharmaceuticals, Inc. (Bristol-Myers Squibb), 345 Park Ave., New York, NY 10154-0004, USA), and the medication was injected. The needle was then extracted, and firm pressure was applied to the puncture site. To minimize potential procedurally related serious adverse events, the patients were screened for anesthesia and corticosteroid sensitivities before the procedure; the puncture site was compressed after needle extraction for at least 1 min and compressed for 3 min in individuals on anticoagulants; a small external diameter 22-g needle was used to reduce tissue trauma and hemorrhage; patients with known anxiety syndromes were given a small prescription of lorazepam and instructed on its emergency use for anxiety at discharge; the patients were educated to recognize post-procedural fever, infection, redness, pain, or unusual swelling and contact us if these were to occur and were instructed to cover the puncture site for 3 days with daily bandage changes and not kneel in the garden or on the ground, use hot tubs, or otherwise contaminate the puncture site; and chlorhexidine for antisepsis was used instead of povidone. Diabetics were instructed to monitor their blood glucose post-injection and temporarily adjust antiglycemic therapy as necessary.

Fig. 1 The arthrocentesis is performed through the superolateral approach with an elastomeric brace applying circumferential (radial) constant compression to the knee and forcing residual fluid where it can be accessed at the superolateral portal. An absorbent impermeable drape can be placed in the access portal to protect the brace (photograph, Wilmer L. Sibbitt, Jr.)

Outcome measures

Patients were observed for serious adverse events including reaction to local anesthesia, post-procedure infections, post-procedural pain, dermal atrophy, post-procedure anxiety or other corticosteroid complications, clinical hemorrhage, deep venous thrombosis, or post-injection visits to emergency facilities, and all subjects were interviewed at 3–12 months to whether any late complications had occurred. Patient pain was measured with the standardized and validated 0–10 cm Visual Analogue Pain Scale (VAS Pain Scale), where 0 cm = no pain and 10 cm = unbearable pain [21]. Pain by VAS was determined prior to the procedure. Aspirated fluid volume was quantified in milliliters (ml) with conventional arthrocentesis, and the additional and total fluid was obtained after application of the constant compression brace. Diagnostic fluid was defined as greater or equal to 2.0 ml (1 ml for culture, and 1 ml for cell counts and crystal examination). Fluid was evaluated for cell counts, crystals, and gram stain, and sent for culture and sensitivity as appropriate.

Statistical analysis Data were entered into Excel (Version 5, Microsoft, Seattle, WA). Standard summary statistics (means, proportions) were calculated for the two groups and statistical analysis was performed with Simple Interactive Statistical Analysis (SISA) (Consultancy for Research and Statistics,

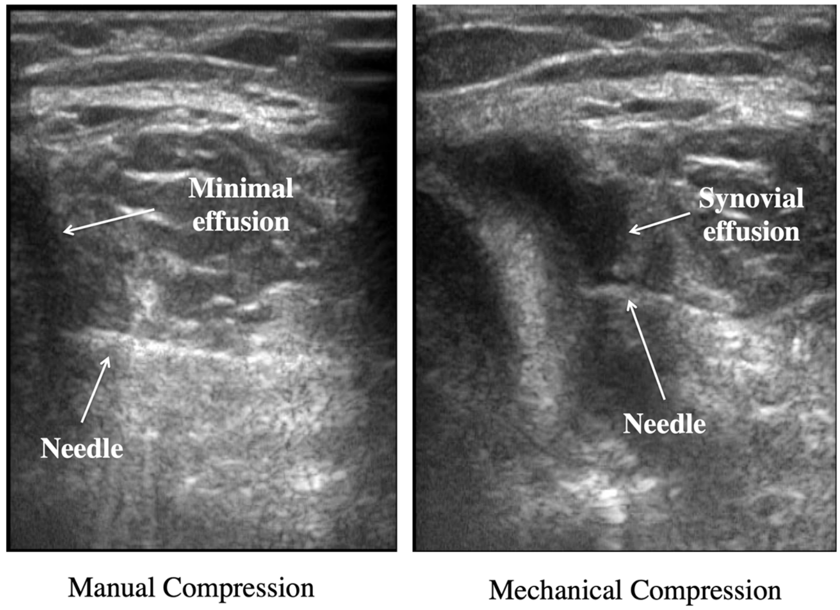

Fig. 2 This ultrasound image demonstrates the lateral recess of the suprapatellar bursa with manual compression versus mechanical constant compression with the elastomeric brace showing substantial shift of intraarticular synovial fluid toward the access point at the lateral recess of the suprapatellar bursa. The aspiration/injection needle can be seen in the effusion on the right-hand side after the constant compression brace has been applied (ultrasound image, Wilmer L. Sibbitt, Jr.)

Lieven de Keylaan 7, 1222 LC Hilversum, the Netherlands; http://www.quantitativeskills.com/sisa/). A power calculation was made using preliminary data at this level where $\alpha = 5\%$, power = 0.9, and allocation ratio = 1.0, indicating that $n = 60$ in each group would provide statistical power at the $p < 0.05$ level and $n = 100$ in each group at the $p < 0.01$ level. Statistical differences between categorical data were determined with Fisher's exact method. Measurement data was analyzed using the paired Student's t test calculating both p values and confidence intervals. p values < 0.05 were considered significant.

Results

There were no serious adverse events encountered by the 253 patients in the cohort including, but not limited to needlestick, infection, septic joint, hemarthrosis, deep venous thrombosis, dermal atrophy, significant bruising, or other hemorrhages.

The beneficial effects of mechanical compression on arthrocentesis success and yield in the rheumatoid and osteoarthritic knee were very similar (Table 1). In the painful rheumatoid knee, mechanical compression decreased failed diagnostic arthrocentesis (< 2 ml) from 56.7% (38/67) to 26.9% (18/67) (− 47.4% change, $p = 0.003$), very similar to the effects of mechanical compression in the painful osteoarthritic knee (Table 1). Similarly, in the painful rheumatoid knee, mechanical compression increased absolute arthrocentesis yield from 4.7 ± 10.3 to 9.8 ± 9.8 ml (108% increase, 95% CI − 8.5043 < − 5.1 < − 1.6957, $p = 0.0038$), again very similar to the results in the painful osteoarthritic knee (Table 1). Although the present study design did not permit this determination, Bennett et al. have demonstrated previously that mechanical compression of the osteoarthritic knee does not increase procedural or post-procedural pain [9]. Thus, the present study demonstrates mechanical compression has the same basic beneficial effect on arthrocentesis in the painful rheumatoid knee as has been demonstrated previously in the painful osteoarthritic knee [6–9].

Direct comparisons between the RA and OA cohorts are shown in Table 2 and Fig. 3. The mean age of the rheumatoid arthritis cohort (55.0 ± 14.5 years) was younger than the osteoarthritis cohort (61.5 ± 11.5, 95% CI of difference 2.6547 < 6.5 < 10.345, $p = 0.001$). Female gender and pre-procedural pain were similar between the two cohorts (Table 2). Failed diagnostic arthrocentesis (< 2 ml) was more common in osteoarthritis versus rheumatoid arthritis without compression (66.7% vs. 56.7% respectively $p = 0.04$) and with mechanical compression (38.2% vs. 29.7% respectively, $p = 0.03$) (Table 2). Conventional arthrocentesis yield was 124% greater in rheumatoid arthritis (4.7 ± 10.3 ml) than osteoarthritis (2.1 ± 6.0 ml), but this did not reach statistical significance ($p = 0.056$). However, total arthrocentesis yield was significantly greater (Fig. 3) with mechanical compression in rheumatoid arthritis (9.8 ± 9.8 ml) than osteoarthritis (5.0 ± 9.4 ml, $p = 0.0008$), and occult extractable fluid was 77% greater (rheumatoid arthritis 5.3 ± 8.7 ml, osteoarthritis 3.0 ± 5.5 ml, $p = 0.046$). Thus, painful rheumatoid arthritis knees had more total extractable fluid in general (96% more) than painful osteoarthritic knees (Fig. 3).

Painful rheumatoid arthritis knees were characterized by more inflammation as characterized by 1570% greater total nucleated cell count in synovial fluid (rheumatoid arthritis 8430 ± 7207, osteoarthritis 497 ± 1189, $p = 0.0001$) and a 342% increase in neutrophil proportion (rheumatoid arthritis 50.6 ± 28.8%, osteoarthritis 11.3 ± 18.9%, $p = 0.0001$) (Table 2). We hypothesized that perhaps the increased extractable synovial fluid volume in rheumatoid arthritis as

Table 1 Mechanical compression-assisted arthrocentesis in painful rheumatoid and osteoarthritic knees

	Conventional	Compression-assisted arthrocentesis	Percent difference (%)	95% CI of difference	p value
Number of rheumatoid knees	67	67			
Failed diagnostic arthrocentesis (< 2 ml)**	56.7% (38/67)	26.9% (18/67)	− 47.4	Not applicable	0.0003
Arthrocentesis yield*	4.7 ± 10.3 ml	9.8 ± 9.8 ml	+ 108	− 8.5043 < − 5.1 < − 1.6957	0.0038
Number of osteoarthritic knees	186	186			
Failed diagnostic arthrocentesis (< 2 ml)**	66.7% (124/186)	38.2% (71/186)	− 43.7	Not applicable	0.0001
Arthrocentesis yield*	2.1 ± 6.0 ml	5.0 ± 9.4 ml	+ 138	− 4.5026 < − 2.9 < − 1.2974	0.0004

*Mean ± standard deviation, two-tailed t test

**Fisher exact test

compared to osteoarthritis was due to greater cellular inflammation; thus, large volume synovial fluid yield in rheumatoid arthritis would be associated with more inflammatory synovial fluid as manifested by increased cell counts and neutrophil proportion compared to low volume yield in rheumatoid arthritis. Thus, we compared high volume (≥ 5 ml) with low volume (< 5 ml) extractable synovial fluid in rheumatoid arthritis (Table 3). Low volume arthrocentesis was associated with a 35% decrease in total nucleated cell count and a 28.4% decrease in neutrophil proportion ($p = 0.04$) compared to a high volume arthrocentesis supporting high volume yields were associated with greater intraarticular inflammation than low volume yields (Table 3). The same analysis in osteoarthritis demonstrated no differences in cell counts in high volume versus low volume effusions suggesting that, unlike rheumatoid arthritis, factors other than synovial fluid cellular inflammation were driving large effusion formation (Table 3).

It was possible that knee effusions were not due to inflammation per se, but rather to mechanical factors related to the amount of joint destruction and instability [17]. Thus, the relationship between arthritis severity (grade) was evaluated (Tables 3). The arthritis grade in large effusion rheumatoid knees (1.74 ± 0.97) was not different from small effusion rheumatoid knees (1.78 ± 1.0, 95% CI of difference − 0.52 < − 0.04 < 0.44, $p = 0.87$) (Table 3). In contrast, the arthritis grade in large effusion osteoarthritic knees (2.49 ± 0.96) was considerably greater than small effusion rheumatoid knees (− 28.9%, 1.77 ± 1.11, 95% CI of difference 0.40 < 0.72 < 1.0, $p = 0.0001$) (Table 3). Thus, large effusions in rheumatoid arthritis knees were associated with increased synovial fluid inflammation and not the degree of joint damage, while large effusions in osteoarthritis knees were associated the degree of established joint damage but not with increased synovial fluid inflammation.

Table 2 The painful knee in rheumatoid arthritis versus osteoarthritis

	Osteoarthritis	Rheumatoid arthritis	Percent difference (%)	95% CI of difference (Wald)	p value
Number of knees	186	67			
Age*	61.5 ± 11.5	55.0 ± 14.5	− 10.6	2.65 < 6.5 < 10.3	0.001
Female gender**	95.2% (177/186)	82.1% (55/67)	− 13.8	Not applicable	0.0015
Pre-procedural pain*	7.6 ± 1.6 cm	7.7 ± 1.8 cm	+ 1.0	− 0.59 < − 0.1 < 0.39	0.68
Failed diagnostic arthrocentesis (< 2 ml)**	66.7% (124/186)	56.7 (38/67)	− 15	Not applicable	0.04
Failed diagnostic arthrocentesis (< 2 ml) with compression**	38.2% (71/186)	26.9% (18/67)	− 29.6	Not applicable	0.03
Conventional arthrocentesis yield (ml)	2.1 ± 6.0 ml	4.7 ± 10.3 ml	+ 124	− 5.2 < − 2.6 < 0.01	0.056
Compression arthrocentesis yield (ml)*	5.0 ± 9.4 ml	9.8 ± 9.8 ml	+ 96	− 7.5 < − 4.8 < − 2.1	0.0008
Occult extractable synovial fluid (ml)*	3.0 ± 5.5 ml	5.3 ± 8.7 ml	+ 77	− 4.5 < − 2.3 < − 0.07	0.046
Total nucleated cell count (cells/ml)*	497 ± 1189	8430 ± 7207	+ 1570	− 9667 < − 7933 < − 6198	0.0001
Neutrophils (%)*	11.3 ± 18.9	50.6 ± 28.8	+ 342	− 46.7 < − 39.3 < − 31.93	0.0001
Lymphocytes (%)*	18.9 ± 15.4	17.4 ± 12.7	− 8.0	− 2.3 < 1.5 < 5.3	0.44
Monocytes (%)*	69.4 ± 23.7	32.5 ± 27.2	− 53.2	29.6 < 36.9 < 44.3	0.0001
Radiographic grade (0–3)*	1.96 ± 1.11	1.76 ± 1.00	− 10.2	− 0.09 < 0.20 < 0.49	0.18

*Mean ± standard deviation, two-tailed t test

**Fisher exact test

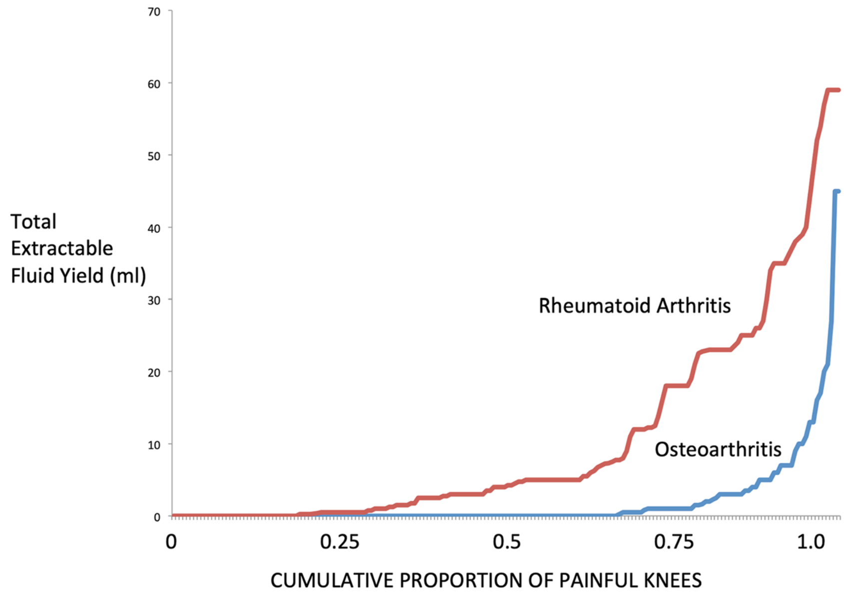

Fig. 3 This graph shows the significantly greater total extractable synovial fluid yield in the painful rheumatoid knee (9.8 ± 9.8 ml, upper line) versus the painful osteoarthritic knee (5.0 ± 9.4 ml, lower line) (+ 96% greater, − 7.5077 < − 4.8 < − 2.0923, $p = 0.0008$) (graph, Wilmer L. Sibbitt, Jr.)

Discussion

Both inflammatory and non-inflammatory arthritis can be complicated by joint effusions that are often aspirated therapeutically to relieve the symptoms associated with joint distention and for synovial fluid analysis to assist in diagnosis and classification [1–5]. Extraction of joint fluid for biomarker and metabolic analysis even in the dry (non-effusive) knee is presently an important area in arthritis research and may also be integral to future joint preservation strategies and therapies [4, 5, 22]. Thus, obtaining at least a minimal volume (usually 2 ml) of synovial fluid is important diagnostically in many patients. Recently, Bhavsar et al. and others have demonstrated that external mechanical compression of the osteoarthritic knee

Table 3 High volume versus low volume arthrocentesis in rheumatoid arthritis and osteoarthritis

	High volume (≥ 5 ml)	Low volume (< 5 ml)	Percent difference (%)	95% CI of difference	*p* value
Rheumatoid arthritis					
Number of knees	24	25			
Age*	56.1 ± 14.7	52.6 ± 16.1	− 6.2	− 5.1 < 3.5 < 12.1	0.43
Female gender**	70.8% (17/24)	88.0% (22/25)	+ 24.3	Not applicable	0.10
Compression arthrocentesis yield (ml)*	25.1 ± 15.1 ml	1.8 ± 1.6 ml	− 92.8	17.2 < 23.3 < 29.4	0.0001
Total nucleated cell count (cells/ml)*	10,265 ± 8323	6669 ± 5380	− 35.0	− 345 < 3596 < 7537	0.08
Neutrophils (%)*	59.2 ± 28.6	42.4 ± 26.6	− 28.4	1.3 < 16.8 < 32.3	0.04
Lymphocytes (%)*	14.5 ± 11.4	20.2 ± 13.3	+ 39.3	− 12.6 < − 5.7 < 1.2	0.12
Monocytes (%)*	27.3 ± 26.1	37.3 ± 27.3	+ 36.6	− 25.0 < − 10 < 5.0	0.20
Radiographic grade (0–3)*	1.74 ± 0.97 ($n = 27$)	1.78 ± 1.0 ($n = 40$)	+ 2.3	− 0.52 < − 0.04 < 0.44	0.87
Osteoarthritis					
Number of knees	37	31			
Age*	64.4 ± 9.5	65.8 ± 9.9	+ 2.2	− 6.0 < − 1.4 < 3.2	0.56
Female gender**	91.9% (34/37)	83.9% (26/31)	− 8.7	Not applicable	0.18
Compression arthrocentesis yield (ml)*	16.4 ± 13.5 ml	2.6 ± 1.6 ml	− 84.1	9.4 < 13.8 < 18.2	0.0001
Total nucleated cell count (cells/ml)*	341 ± 253	433 ± 603	+ 27.0	− 319. <− 92 < 135	0.44
Neutrophils (%)*	11.5 ± 17.6	11.7 ± 18.4	+ 1.0	− 8.8 < − 0.2 < 8.4	0.96
Lymphocytes (%)*	18.2 ± 13.4	15.7 ± 11.9	− 13.7	− 3.5 < 2.5 < 8.5	0.42
Monocytes (%)*	69.8 ± 22.9	73.8 ± 20.4	+ 5.7	− 14.3 < − 4 < 6.3	0.48
Radiographic grade (0–3)*	2.49 ± 0.96 ($n = 51$)	1.77 ± 1.11 ($n = 135$)	− 28.9	0.40 < 0.72 < 1.0	0.0001

*Mean ± standard deviation, two-tailed *t* test

**Fisher exact test

resulted in improved arthrocentesis success and yield beyond conventional arthrocentesis by mobilizing occult extractable fluid in both the clinically dry and the effusive knee [7–9].

The present study confirms that external mechanical compression also improves arthrocentesis success and yields in the rheumatoid knee in a fashion very similar to the osteoarthritic knee (Table 1; Fig. 3). Thus, as in osteoarthritis of the knee, external mechanical compression should be useful to permit a higher rate of diagnostic arthrocentesis success and more complete therapeutic arthrocentesis in the painful rheumatoid arthritis knee [6–9].

There are compelling reasons to completely aspirate any joint with inflammatory arthritis prior to injection. Firstly, in the knee with acute inflammation, it is crucial to obtain a diagnostic synovial fluid sample and definitively exclude infection prior to injection [1–5]. Secondly, it has been shown that it is important to therapeutically completely decompress the joint prior to injection of a medication [23–26]. In 2003, Weitoft et al. demonstrated that complete aspiration of the knee with inflammatory arthritis prior to corticosteroid injection prolonged the asymptomatic period and time-to-flare and, thus, reduced the need for repetitive corticosteroid injection [23]. Recently, Bennett et al. have confirmed a similar beneficial effect of complete arthrocentesis prior to corticosteroid injection in the painful osteoarthritic knee [9]. A number of other studies have demonstrated that it is important to accurately place the needle intraarticularly, preferably with demonstrated synovial fluid return to confirm intraarticular positioning, and to completely aspirate as much synovial effusion as possible prior to injection in order to improve joint injection outcomes [9, 24–26].

The failure of full synovial fluid extraction during a conventional arthrocentesis may be due to a combination of a small target effusion that is easily missed, operator mistargeting of the effusion by the needle, the complex intraarticular synovial compartments and foldings of the villi that trap viscous fluid, fluid (edema) trapped in edematous villi and synovial membrane, ineffective manual compression, resistance to movement of fluid due to the semi-solid gel-like properties of synovial fluid, and its non-Newtonian elasticity and viscosity [6–9, 22, 27]. External mechanical compression is increasing, recognized as reliable method to fully aspirate all extractable synovial fluid with or without ultrasound guidance [6–9, 28]. In 2008, Meehan proposed the use of an external compression device for joint aspiration, and in 2015, Meehan and colleagues demonstrated that this methodology can move fluid to where it is more accessible [6, 28]. Recently, Bhavsar et al., Bennett et al., and Yaqub et al. have also demonstrated improved arthrocentesis success and yield in osteoarthritis with mechanical compression [7–9]. The present study demonstrates that external mechanical compression in the rheumatoid knee (Fig. 1) also dilates the joint space to be targeted (Fig. 2) as has been shown in osteoarthritis and takes advantage of the classic rheological properties of synovial fluid to permit fluid flow to the needle access point, enhancing fluid aspiration (Fig. 3) [5–9, 28].

Magnetic resonance imaging, radiographic, and synovial fluid studies of the osteoarthritic knee have demonstrated that synovial fluid effusion volume is not as closely related to inflammation as measured by gadolinium contrast and inflammatory cell counts in synovial fluid as is the case in rheumatoid arthritis but rather effusions are more closely related to synovial membrane hypertrophy, cytokine disturbance, and mechanical factors [1–5, 12–15]. The present study demonstrates that in the painful osteoarthritic knee, large volume versus small volume extractable fluid has no difference in inflammatory cell counts or neutrophil proportion but rather increased fluid is associated with advanced arthritis grade (degree of mechanical destruction of the joint) (Table 3) [1–5, 12–15].

In contrast, magnetic resonance imaging, radiographic, and synovial fluid studies of the rheumatoid knee have demonstrated that synovial fluid effusion volume is closely related to inflammation as measured by gadolinium contrast, cytokine disturbances, and inflammatory cell recruitment into synovial fluid [1–5, 29–31]. The present study also supports the importance of local inflammation in effusion formation in inflammatory arthritis as the cell counts and proportion of neutrophils were highest in large volume versus small volume effusions in the painful rheumatoid knee (Table 3). Further, there was no difference in the arthritis grade or degree of mechanical destruction in large volume versus small volume synovial effusions in rheumatoid arthritis (Table 3).

One limitation to this study is that ultrasound was not used to confirm complete decompression of the knee of all extractable fluid [6, 7]. On the other hand, most knee arthrocenteses are still performed without ultrasound so this present study most closely resembles dominant contemporary clinical practice [19, 20]. Further, although ultrasound can identify discrete fluid within the imaging limits, ultrasound does not positionally shift fluid where it can pool and then can be accessed. Another important limitation of this study is that we did not evaluate whether the additional fluid expressed with compression was identical to the fluid obtained with the standard arthrocentesis procedure. The present study used an elastomeric compression brace; it is anticipated that commercially available pneumatic compression braces for arthrocentesis would have a similar effect [32]. Another limitation to this study is the paired study design that, although providing a robust structure for determining improvements in individual residual arthrocentesis yield and permitting direct comparisons between rheumatoid arthritis and osteoarthritis of the knee, could not determine effects or benefits of enhanced arthrocentesis on injection outcomes.

Conclusion

The success of diagnostic and therapeutic knee arthrocentesis of the painful rheumatoid knee can be significantly improved through the application of mechanical compression to mobilize occult extractable synovial fluid. Increased extractable fluid yield is characterized by higher neutrophil counts in the rheumatoid knee but not in the osteoarthritic knee. Increased extractable fluid in the osteoarthritis knee is associated with a higher degree of mechanical destruction in that knee, but this effect is not observed in the rheumatoid knee. These differences indicate divergent etiologies for large effusion formation in the painful rheumatoid knee versus the painful osteoarthritic knee. Mechanical compression of the rheumatoid knee is a simple and low-cost quality improvement technique that can readily be incorporated into the care of patients with rheumatoid arthritis.

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Compliance with ethical standards

Ethical standards All human and animal studies have been approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All persons gave their informed consent prior to any procedures and prior to the inclusion in the study.

Disclosures None.

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