Pressure generated by syringes: implications for hydrodissection and injection of dense connective tissue lesions

WAP Hayward[1], LJ Haseler[2], LG Kettwich[3], AA Michael[4], WL Sibbitt Jr[3], AD Bankhurst[3]

[1]Lonestar Montgomery College, The Woodlands, TX, USA, [2]Heart Foundation Research Center, Griffith University, Gold Coast, Australia, [3]Department of Internal Medicine, University of New Mexico Health Sciences Center, Albuquerque, NM, USA, and [4]Department of Internal Medicine, Texas Tech Health Sciences Center, El Paso, TX, USA

Objective: Hydrodissection and high-pressure injection are important for the treatment of dense connective tissue lesions including rheumatoid nodules, Dupuytren's contracture, and trigger finger. The present study determined the optimal syringes for high-pressure injection of dense connective tissue lesions.

Methods: Different sizes (1, 3, 5, 10, 20, and 60 mL) of a mechanical syringe (reciprocating procedure device) with a luer-lock fitting were studied. Twenty operators generated maximum pressure with each mechanical syringe size, and pressure was measured in pounds per square inch (psi). Subsequently, 223 dense connective tissue lesions were injected with different sizes of syringes (1, 3, or 10 mL). Outcomes included (i) successful intralesional injection and (ii) clinical response at 2 weeks.

Results: Smaller syringes generated significantly more injection pressure than did larger syringes: 1 mL (363 ± 197 psi), 3 mL (177 ± 96 psi), 5 mL (73 ± 40 psi), 10 mL (53 ± 29 psi), 20 mL (32 ± 18 psi), and 60 mL (19 ± 12 psi). Similarly, smaller syringes were superior to larger syringes for intralesional injection success: 10 mL: 34% (15/44) vs. 1 mL: 100% (70/70) ($p < 0.001$) and 3 mL: 91% (99/109) ($p < 0.001$).

Conclusion: Smaller syringes (≤ 3 mL) are superior to larger syringes (≥ 5 mL) for successful hydrodissection and high-pressure intralesional injection of dense connective tissue lesions.

Dense connective tissue lesions amenable to high-pressure injection with corticosteroid or collagenase include Dupuytren's contracture, rheumatoid nodules, and trigger finger (1–5). Low-pressure injection on the exterior of the lesion can result in undesirable atrophy of adipose tissue, skin, and tendinous structures while failing to treat the lesion (6–9). The alternative, a high-pressure injection technique termed 'hydrodissection' is increasingly used in both conventional and image-guided procedures, and uses a pressurized injectant to dilate contracted structures and potential spaces, lyse adhesions, and separate and push away the tendinous, neural, and vascular structures prior to injecting medication (2, 5, 9–13). We hypothesized that smaller syringes would predictably generate higher injection pressure, and thus would be superior for the intralesional injection of dense connective tissue lesions. The present study investigated the effect of syringe size and type on the operator's ability to generate hydrodissection pressure and to successfully inject dense connective tissue lesions.

Wilmer L Sibbitt Jr., MSC 10 5550, Department of Internal Medicine, 5th FL ACC, University of New Mexico Health Sciences Center, Albuquerque, NM 87131, USA.
E-mail: wsibbitt@salud.unm.edu

Accepted 3 February 2011

Materials and methods

Subjects

This trial complied with the Helsinki Declaration, was approved by the institutional review board (IRB), and is registered at clinicaltrials.gov (registration number NCT00651625). Twenty operators generated maximum pressure with different sizes of syringes. Subsequently, hydrodissection and corticosteroid injection of 223 dense connective tissue lesions including 84 rheumatoid nodules, 38 nodules of Dupuytren's contracture, and 101 trigger fingers at the level of the A1 pulley were performed.

Syringes

The mechanical syringe, the reciprocating procedure device (RPD, AVANCA Medical Devices, Inc, 600 Central Ave SE, Ste 232, Albuquerque, NM 87102, USA; www. AVANCAMedical.com) with a luer-lock fitting was used. Mechanical syringes provide enhanced needle control and the ability to generate pressure or vacuum (11–13).

DOI: 10.3109/03009742.2011.560892

Table 1. Hand-generated maximal pressures of different sizes of syringe.

Size of mechanical syringe (mL)	Experimental maximum pressure, mean ± SD (psi)	Significance from next smaller syringe size, p-value	Calculated maximum pressure, mean ± SD (psi)	Significance from experimental maximum pressure, p-value	Maximum pressure relative to the 10 mL syringe	Maximum pressure relative to the 3 mL syringe
1	363 ± 197	Not applicable	472 ± 256	0.14	6.89	2.05
3	177 ± 96	0.001	195 ± 106	0.58	3.36	1.00
5	73 ± 40	0.001	77 ± 42	0.76	1.39	0.41
10	53 ± 29	0.08	55 ± 30	0.83	1.00	0.30
20	32 ± 18	0.005	33 ± 18	0.86	0.61	0.18
60	19 ± 12	0.01	19 ± 12	No difference	0.34	0.11

Pressure generation

Pressure was measured in pounds per square inch (psi) with a digital pressure meter (DPM-2000 Digital Pressure Meter, BC Group, Chicago, IL, USA). The operator generated maximum pressure with one hand with each syringe size (from 1 mL to 60 mL). The order of syringe size was randomized to prevent a consistent or training bias. Theoretical pressures were calculated from the experimental results of the 60 mL syringe and adjusted for syringe size.

Injection of dense connective tissue lesions

For injection of rheumatoid nodules and Dupuytren's contracture, the target was the centre of the nodule. The target for trigger finger was the tendon sheath overlying the palmar protuberance of the metacarpal head just proximal to the A1 pulley and the digital-palmar skin crease (5). After antisepsis with 2% chlorhexidine (ChloraPrep®, Cardinal Health, Inc., Dublin, OH, USA), a 25-gauge 1-inch needle (305761, 25 g 1.0″ BD Eclipse™ Needle, Becton Dickinson, Inc, Franklin Lakes, NJ, USA) mounted on a 1, 3, or 10 mL mechanical syringe with 1.5 mL of 2% lidocaine (Xylocaine® 2%, AstraZeneca Pharmaceuticals LP, Wilmington, DE, USA) was advanced until the target tissue was hydrodissected and intralesionally injected with lidocaine. Successful hydrodissection was defined as: (i) rupture or deformation of the rheumatoid nodule from the internal pressure, (ii) the deformation of the fibrotic nodule of Dupuytren's contracture, and (iii) dilation of the tendon sheath of the trigger finger target, respectively. If the lesion could not be injected with the 3 mL or the 10 mL syringe because of inadequate pressure, the needle was left in place, the syringe was removed, a 1 mL syringe with lidocaine was attached, and the hydrodissection procedure completed. In this way all of the hydrodissection procedures were successfully completed prior to corticosteroid injection. After hydrodissection, the needle was left in position, the first syringe removed, and a syringe with triamcinolone acetonide attached. Small rheumatoid nodules were injected with 0.25 mL (10 mg) and large rheumatoid nodules, Dupuytren's contracture, and trigger fingers with 0.5 mL (20 mg) triamcinolone acetonide suspension (Kenalog® 40, Westwood-Squibb Pharmaceuticals, Inc (Bristol-Myers Squibb), New York, NY, USA).

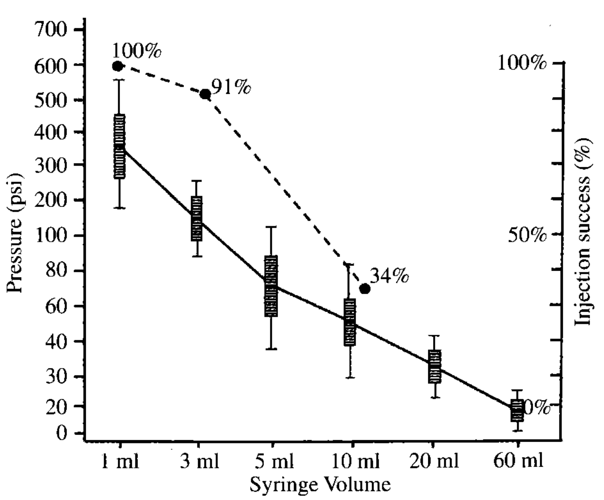

Figure 1. Effect of syringe size on manual pressure generation and injection success. The solid line represents pressure generation for each syringe in pounds per square inch (psi) and the dashed line the percentage initial injection success with each size mechanical syringe. As can be seen, the smaller 1 mL and 3 mL syringes have both high levels of pressure generation and high levels of injection success of dense connective tissue lesions compared to the 10 mL syringe.

Outcome measures

Procedural pain was assessed with the 0–10 cm visual analogue pain scale (VAS) (11, 12). Response was defined at 2 weeks as (i) a 50% or more reduction in the diameter of the rheumatoid nodule or Dupuytren's lesion, or (ii) complete resolution of the trigger finger (1–5).

Statistical analysis

Data were entered into Excel (Version 5, Microsoft, Seattle, WA, USA) and analysed in SAS (SAS/STAT Software, Release 6.11, Cary, NC, USA). Differences in categorical data were determined with Fisher's exact test and differences in parametric data with the t-test, while differences between multiple parametric data sets were determined with Fisher's least significant difference method.

Table 2. Effect of syringe size on injection success and outcome.

	Rheumatoid nodules n = 84	Dupuytren's contracture n = 38	Trigger finger n = 101	Total dense connective tissue lesions
Initial success with 1 mL syringe	100% (31/31)	100% (15/15)	100% (24/24)	100% (75/75)
	p = 0.0001 relative to 10 mL	p = 0.0002 relative to 10 mL	p =0.03 relative to 10 mL	p = 0.0001 relative to 10 mL
Initial success with 3 mL syringe	78% (25/32)	92% (11/12)	97% (63/65)	91% (99/109)
	p = 0.001 relative to 10 mL	p = 0.001 relative to 10 mL	p = 0.003 relative to 10 mL	p = 0.0001 relative to 10 mL
Initial success with 10 mL syringe	33% (7/21)	27% (3/11)	42% (5/12)	34% (15/44)
Procedural pain, VAS (cm)	2.3 ± 1.8	4.2 ± 2.4	6.1 ± 3.5	4.3 ± 2.6
Percentage clinical response	100 (84/84) (> 50% reduction in diameter of lesion)	83 (31/38) (> 50% reduction in diameter of lesion)	84 (85/101) (resolution of trigger finger)	90 (200/223)
Complications	13% (11/84) with dermal atrophy	5% (2/38) with dermal atrophy	5% (5/101) with dermal atrophy	8% (18/223) with dermal atrophy

Results

The calculated pressures were slightly greater than the measured pressures, but did not reach statistical significance (Table 1). Smaller syringes generated higher pressures up to 600 psi for a 1 mL syringe, while larger syringes generated proportionately lower pressures (Figure 1). The 3 mL syringe generated four times greater pressure than the 10 mL syringe; the 1 mL generated seven times greater pressure than the 10 mL syringe (Table 1). Thus, the 1 mL and 3 mL syringes consistently generated high levels of pressure (300–600 psi) while the 5, 10, 20, and 60 mL syringes generated markedly lower levels of pressure (9–150 psi).

The injection success of dense connective tissue lesions paralleled the ability to generate high pressure (Figure 1, Table 2). The 1 mL and 3 mL mechanical syringes provided an initial success rate of 100% and 93%, respectively, in hydrodissection and intralesional injection. However, the 10 mL mechanical syringe had a failure rate of 76%. Procedural pain was highest for trigger finger, intermediate for Dupuytren's contracture, and the least for rheumatoid nodules (Table 2). The clinical results of failed hydrodissection could not be assessed because when initial injection failed, the procedure was completed with a 1 mL syringe. The clinical results for hydrodissection and injection of dense connective lesions were generally excellent, with significant reduction in size of the nodules or resolution of trigger finger with low levels of dermal atrophy consistent with rates reported in the literature (Table 2) (1–9).

Discussion

This report demonstrates that hydrodissection and intralesional injection of dense connective tissue lesions can be predictably achieved with smaller syringe sizes ($\leq$ 3 mL) (Figure 1, Tables 1 and 2). With syringes $\leq$ 3 mL, levels of pressure up to 600 psi for hydrodissection and corresponding levels of injection success are possible (Tables 1 and 2). By contrast, larger syringe sizes $\geq$ 5 mL are associated with lower levels of pressure and reduced rates of injection success (Figure 1, Tables 1 and 2).

Syringe size has been a concern to proceduralists, especially in relation to needle control and vacuum generation (13–15). Smaller syringes provide consistently better needle control than do larger syringes (13). By contrast, larger syringes, including the 10, 20, and even 60 mL, generate higher levels of vacuum and are recommended for suction biopsy procedures (15). The present study demonstrates that smaller syringes predictably generate greater pressure and correspondingly improved intralesional injection success. The pressure in a syringe is determined by the force generated by the hand and applied to the plunger divided by the cross-sectional surface area of the barrel. The hand force to generate maximum pressure is limited by the operator's native hand and arm musculature. As the cross-sectional surface area of the syringe barrel increases progressively from the 1 mL to the 60 mL syringe, the maximum possible pressure generated by hand force decreases as the syringe size increases (Table 1, Figure 1).

These findings are also consistent with prior reports that demonstrate that corticosteroid injection is effective for dense connective tissue lesions, including rheumatoid nodules, Dupuytren's contracture, and trigger finger (1, 3–5). Although there was a low incidence of dermal atrophy with high-pressure intralesional injections in this study, it is anticipated that low-pressure extralesional injection outside of dense connective tissue lesions would result in higher levels of complications (6–8). Furthermore, the precise intralesional injection of collagenase into the dense connective tissue lesions of Dupuytren's contracture and Peyronie's disease also requires high pressures for success, and the present study provides guidance as to appropriate syringe selection to achieve these high levels of pressure (2). Furthermore, as hydrodissection and high-pressure injections become increasingly used in minimally invasive therapies, the selection of the appropriate syringe devices is important to achieve predictable levels of pressure and injection success while avoiding complications, device failure, and a failed procedure (2, 9–12).

In summary, the present study demonstrates that smaller syringes ($\leq$ 3 mL) permit more robust pressure generation than do larger syringes, and thus facilitate predictably successful intralesional hydrodissection and injection of dense connective tissue lesions.

References

1. Ketchum LD, Donahue TK. The injection of nodules of Dupuytren's disease with triamcinolone acetonide. J Hand Surg (Am) 2000;25:1157–62.
2. Gilpin D, Coleman S, Hall S, Houston A, Karrasch J, Jones N. Injectable collagenase *Clostridium histolyticum*: a new nonsurgical treatment for Dupuytren's disease. J Hand Surg Am 2010;35:2027–38.
3. Baan H, Haagsma CJ, van de Laar MA. Corticosteroid injections reduce size of rheumatoid nodules. Clin Rheumatol 2006;25:21–3.
4. Peters-Veluthamaningal C, Winters JC, Groenier KH, Meyboom-de Jong B. Corticosteroid injections effective for trigger finger in adults in general practice: a double-blinded randomized placebo controlled trial. Ann Rheum Dis 2008;67:1262–6.
5. Sibbitt WL Jr, Eaton RP. Corticosteroid responsive tenosynovitis is a common pathway for limited joint mobility in the diabetic hand. J Rheumatol 1997;24:931–6.
6. Gottlieb NL, Riskin WG. Complications of local corticosteroid injections. J Am Med Assoc 1980;243:1547–8.
7. Amin N, Brancaccio R, Cohen D. Cutaneous reactions to injectable corticosteroids. Dermatitis 2006;17:143–6.
8. Taras JS, Iiams GJ, Gibbons M, Culp RW. Flexor pollicis longus rupture in a trigger thumb: a case report. J Hand Surg (Am) 1995;20:276–7.
9. Gimbel HV. Hydrodissection and hydrodelineation. Int Ophthalmol Clin 1994;34:73–90.
10. Mejia R, Saxena P, Tam RK. Hydrodissection in redo sternotomies. Ann Thorac Surg 2005;79:363–4.
11. Sibbitt WL Jr, Peisajovich A, Michael AA, Park KS, Sibbitt RR, Band PA, et al. Does sonographic guidance influence the outcome of intraarticular injections? J Rheumatol. 2009;36:1892–902.
12. Sibbitt WL Jr, Band PA, Chavez-Chiang NR, Delea SL, Norton HE, Bankhurst AD. A randomized controlled trial of the cost-effectiveness of ultrasound-guided intraarticular injection of inflammatory arthritis. J Rheumatol 2011;38:252–63.
13. Michael AA, Park KS, Moorjani GR, Peisjovich A, Sibbitt WL Jr, Bankhurst AD. Syringe size: does it matter in physician performed procedures? J Clin Rheumatol 2009;15:56–60.
14. Sibbitt RR, Sibbitt WL Jr, Nunez SE, Kettwich LG, Kettwich SC, Bankhurst AD. Control and performance characteristics of eight different suction biopsy devices. J Vasc Interv Radiol 2006;17:1657–69.
15. Haseler LJ, Sibbitt RR, Sibbitt WL Jr, Michael AA, Gasparovic CM, Bankhurst AD. Syringe and needle size, syringe type, vacuum generation, and needle control in aspiration procedures. Cardiovasc Intervent Radiol 2010 Nov. 6 [Epub ahead of print], doi:10.1007/s00270-010-0011-z.