RECONSTRUCTIVE

Strategies for Postoperative Seroma Prevention: A Systematic Review

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Background: There is conflicting evidence on the effectiveness of the various strategies to prevent postoperative seroma. Many high-quality studies have been performed to evaluate those strategies, but the numbers of patients included in those studies have been small. The authors' goal was to perform a systematic review of all Level I and II studies on the prevention of postoperative seroma. **Methods:** A PubMed search was performed of all Level I and II studies that evaluated strategies for the prevention of postoperative seroma. Only English-language comparative studies on humans, defining seroma as a postoperative serous fluid collection detectable on physical examination, were included. Data from all the studies were compiled, and a systematic review was performed to evaluate the effectiveness of each strategy.

Results: Seventy-five studies comprising 7173 patients were included. Effective strategies for seroma prevention included the use of closed-suction drains; keeping the drains until their output volume was minimal; maintaining a high pressure gradient in the drains; using sharp or ultrasonic dissection rather than cautery; dissecting the abdomen in a place superficial to the Scarpa fascia; ligating blood vessels with sutures or clips; using quilting or progressive tension sutures; using fibrin, thrombin, or talc; and immobilizing the surgical site postoperatively. Surgical-site compression did not prevent seroma accumulation. The use of sclerosants at the initial operation actually increased the risk of seroma.



Conclusions: Seroma is a common and frustrating complication in plastic surgery. This study demonstrates that simple strategies can be used to lower the risk of seroma. (*Plast. Reconstr. Surg.* 138: 240, 2016.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, II.

Service of surgical procedures where anatomical dead space is created.¹ Not only do seromas often cause patient discomfort,² they also usually require multiple percutaneous aspirations, and possibly additional surgical procedures.³ In addition, seromas carry the risk of becoming infected, resulting in an abscess.

Numerous studies have been performed to evaluate the effectiveness of various strategies to reduce the incidence of postoperative seromas. The vast majority of those studies, however, are retrospective and noncomparative in nature,⁴ making

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Copyright © 2016 by the American Society of Plastic Surgeons DOI: 10.1097/PRS.00000000002245 the deduction of valuable conclusions difficult. A number of prospective, randomized, controlled trials have been performed. Those trials have evaluated the effects of factors such as dissection method, postoperative immobilization, postoperative compression, drains, fibrin glue, talc, quilting sutures, and others on the incidence of seroma formation. Many of those studies included small numbers of patients, and reached conflicting conclusions.^{5,6} Our purposes in this study were to review the literature on seroma prevention and treatment, and to perform a comprehensive systematic review of randomized controlled trials and comparative prospective studies that evaluated strategies to reduce the incidence of postoperative seroma.

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PATIENTS AND METHODS

A database search in PubMed was performed for all articles containing the terms "seroma," "fibrin," "quilting," "progressive tension sutures," or "sclerosant." We only included English-language randomized controlled trials and prospective comparative studies that defined seroma as a postoperative serous fluid collection at the surgical site that is evident on physical examination. Level I studies were defined as high-quality randomized controlled trials with adequate power, and Level II studies were defined as lesser quality randomized controlled trials and nonrandomized prospective studies. A systematic review was performed to evaluate the effect of the following variables on the incidence of postoperative seroma: the use of drains (yes versus no), time to drain removal (time-controlled versus volume-controlled), intensity of drain vacuum (high versus low), method of tissue dissection (sharp versus cautery versus ultrasonic), method of vessel ligation (cautery versus suture/clip), dissection plane in abdominoplasty (sub-Scarpa versus supra-Scarpa), use of quilting/ progressive tension sutures (yes versus no), use of sclerosant (yes versus no), use of fibrin (yes versus no), use of talc (yes versus no), postoperative immobilization (yes versus no), and postoperative compression (yes versus no). To analyze the effectiveness of each strategy, the results of all trials that analyzed that strategy were compiled, and the rate of seroma formation was compared with and without that strategy, using chi-square analysis, with a value of p < 0.05 indicating statistical significance. The relative risk for seroma occurrence was calculated for each variable. The Grading of Recommendations Assessment, Development and Evaluation Working Group approach was used to assess heterogeneity, quality of evidence, and strength of recommendation for each seroma prevention measure.⁷ According to Cochrane guidelines, heterogeneity (I^2) below 50 percent was considered low, heterogeneity between 50 percent and 75 percent was considered moderate, and heterogeneity above 75 percent was considered high.⁸ The quality of evidence (high, moderate, low, and very low) was assessed based on the type of study, the presence of study design limitations, indirectness, heterogeneity and imprecision, and the probability of bias, following the Cochrane approach.9 The strength of recommendation (strong, weak) depended on four factors: riskto-benefit ratio of the intervention, strength of evidence for or against the intervention, values/ preferences of patients and physicians toward the

intervention and the outcome, and cost of intervention and outcome. $^{10}\,$

RESULTS

Articles Included

The initial search yielded 54,936 articles. The articles were sorted manually to exclude those not relevant to our topic or in languages other than English, yielding 175 articles. The references cited in those articles were searched for relevant citations, yielding an additional 26 articles, for a total of 201 articles. Only randomized controlled trials and prospective comparative trials were included, yielding 75 articles including 7173 patients that were used for the systematic review (Fig. 1). Figure 2 summarizes our results, and Table 1 details the analysis used to determine the quality of the evidence and the strength of the recommendation for each strategy. Table 2 summarizes the various seroma prevention strategies arranged by body region.

Use of Drains

Fourteen randomized controlled trials including 2263 patients analyzed the use of closedsuction drains postoperatively (six articles on the abdomen, seven on the breast, and one on the face).^{5,6,11-22} Four of those studies found a significant reduction in seromas with the use of drains, whereas 10 did not. Considered in aggregate, there was a significant reduction in the rate of seromas with the use of drains (18.5 percent versus 27 percent; p < 0.001; $I^2 = 41$ percent, indicating low heterogeneity). The relative risk for seroma with the use of drains was 0.69 (95 percent CI, 0.58 to 0.8) (quality of evidence, low; strength of recommendation, strong).

Time to Drain Removal

Six randomized controlled trials including 646 patients compared time-controlled to volumecontrolled drain removal (all in the breast).^{23–28} Four of those studies found that waiting to remove drains until their output was below 20 to 50 cc over a 24-hour period resulted in significantly fewer seromas than removing drains at a predetermined time postoperatively. Considered in aggregate, there was a significantly lower rate of seromas with volume-controlled drain removal compared to time-controlled removal (25.5 percent versus 45.1 percent; p < 0.001; $I^2 = 82$ percent, indicating high heterogeneity), with a relative risk of 0.57 (95 percent CI, 0.45 to 0.71) (quality of



Fig. 1. Article selection for the systematic review.

evidence, very low; strength of recommendation, strong).

Intensity of Drain Vacuum

Three randomized controlled trials including 304 patients compared high-vacuum (500 to 750 mmHg) to low-vacuum (100 to 250 mmHg) closed-suction drainage (all in the breast).²⁹⁻³¹ None of those studies found a significant difference between the two vacuum levels. Considered in aggregate, there was a significantly lower rate of seroma when high vacuum was used compared to low vacuum (15.3 percent versus 24.8 percent; p = 0.04; $I^2 = 53$ percent, indicating moderate heterogeneity), with a relative risk of 0.62 (95 percent CI, 0.39 to 0.98) (quality of evidence, very low; strength of recommendation, strong).

Dissection Method

Twelve studies including 1022 patients compared the use of cautery, ultrasonic dissection, and sharp dissection (10 in the breast and two in the abdomen).³²⁻⁴³ Five of those studies found ultrasonic dissection or sharp dissection to result in lower rates of seroma than cautery. Considered in aggregate, sharp dissection resulted in the lowest rate of seroma (15.4 percent), followed by ultrasonic dissection (19.4 percent) and cautery

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Fig. 2. Effectiveness of various strategies at preventing postoperative seroma.

(28.3 percent). The differences between cautery and sharp dissection, and cautery and ultrasonic dissection were significant (p < 0.001). The relative risk for seroma with sharp dissection compared to cautery was 0.54 (95 percent CI, 0.37 to 0.79; $I^2 = 68$ percent, indicating moderate heterogeneity), and the relative risk with ultrasonic dissection compared to cautery was 0.6 (95 percent CI, 0.52 to 0.89; $I^2 = 31$ percent, indicating low heterogeneity) (quality of evidence, low; strength of recommendation, weak).

Method of Vessel Ligation

One prospective study including 90 patients compared clip/suture ligation of perforators to cautery in abdominoplasty.² Clip/suture ligation resulted in a lower rate of seroma compared to cautery (6.7 percent versus 33.3 percent; p < 0.001), with a relative risk of 0.2 (95 percent CI, 0.07 to 0.59) (quality of evidence, very low; strength of recommendation, weak).

Dissection Plane in Abdominoplasty

One randomized controlled trial including 160 patients compared dissection superficial to Scarpa fascia to dissection deep to Scarpa fascia in abdominoplasty.⁴⁴ Superficial dissection resulted in a lower rate of seroma compared with deep dissection (2.5 percent versus 18.75 percent; p < 0.001), with a relative risk of 0.13 (95 percent CI, 0.03 to 0.56) (quality of evidence, very low; strength of recommendation, weak).

Quilting and Progressive Tension Sutures

Eleven randomized controlled trials including 793 patients analyzed the use of quilting and progressive tension sutures (one in the abdomen, five in the back, and five in the breast).^{11,26,45–53} Ten of those studies found a significant reduction in seroma formation with the use of quilting or progressive tension sutures. Considered in aggregate, there was a significant reduction in the rate of seroma with the use of quilting and progressive tension sutures (27.2 percent versus 44.3 percent; p < 0.001; $I^2 = 60$ percent, indicating moderate heterogeneity), with a risk ratio of 0.61 (95 percent CI, 0.5 to 0.75) (quality of evidence, low; strength of recommendation, strong).

Preventive Use of Sclerosant

Three randomized controlled trials including 172 patients analyzed the use of sclerosing substances in a preventive manner during the initial surgical procedure (one in the groin and two in the breast).^{54–56} All three studies used tetracycline as a sclerosant. Two of those studies found a significant increase in the rate of seroma with the use of sclerosant. Considered in aggregate, there was

Seroma				Quality Ass	essment				Effect			
Prevention Measure	No. of Studies	besign	Study Design Limitation	Indirectness	Heterogeneity	Imprecision	Risk of Bias	Other Considerations	RR (95% CI)	p = Evid	ity of ence I	Strength of Recommendation
Use of drains	14	RCTs	No blinding ^a	Serious ^b	Low ^c	Low ^d	High ^e	Large effect	0.69	<0.001 Low	St	rong
Volume-controlled	9	RCTs	No blinding ^a	Serious ^h	High ^{c,g}	Low	$\mathrm{High}^{\mathrm{e}}$	size Large effect	(0.58-0.8) 0.57	<0.001 Very	low St	rong
drain removal High drain vacuum	60	RCTs	No blinding ^a	Serious ^h	Moderate	High ⁱ	Low	SIZE	0.62	0.04 Very	low St	rong
Sharp dissection	9	5 RCTs, 1 prospective nonrandomized	No blinding ^a , one study not	Serious ^b	Moderate	Low	Low	Large effect (0.37-0.79	<0.001 Low	м	leak
Ultrasonic	8	study RCTs	randomized [*] No blinding ^a	Serious ^b	Low	High ⁱ	Low ¹	Large effect	0.6	<0.001 Low	Μ	leak
Clip/suture vessel	1	Prospective nonran-	No blinding ^a ,	Serious ^m	N/A	Low	High ⁿ	Large effect	0.22-0.39)	<0.001 Very	low W	'eak
Superficial dissection plane	1	domized study RCT	nontanuoniizea No blinding ^a	Serious ^m	N/A	Low	Low	Large effect (0.03-0.56	<0.001 Very	low W	<i>l</i> eak
(abdominoplasty) Quilting/PTS	11	8 RCTs, 3 prospective nonrandomized	3 studies blinded, 3 studies	Serious°	Moderate	Low	High ^{n,p}	Large effect size	0.61 (0.5-0.75)	<0.001 Low ^p	St	rong
Preventive use of sclerosants	60	study RCTs	nonrandomized [*] 2 studies blinded, 1 study	Serious	Moderate	High	Low		1.49 1.07-2.07	0.01 Very	low W	leak recommenda- tion against
Preventive use of fibrin/thrombin	15	13 RCT, 2 prospective nonrandomized	terminated early ^f 2 studies nonrandomized ^k	Serious	Low	High	High⁴		$0.72 \\ 0.54-0.95)$	0.02 Low	М	Jeak
Preventive use	1	Prospective non-	Nonrandomized,	Serious ^r	N/A	Low	Low	Large effect	0.13	<0.001 Very	low W	'eak
or tate Surgical-site	4	randonized study RCTs	No blinding ^a	Serious ^h	High	Low	Low	Large effect	0.57	<0.001 Mode	erate W	⁷ eak
Surgical-site compression	73	RCTs	No blinding ^a	Serious	Low	Hight	Low	9126	0.74 - 1.31	0.9 Very	low W	leak recommenda- tion against
RR, relative risk; RCI Quality of evidence r ⁹ Quality of evidence r ⁹ Mostly studies on abc ¹ friconsistency among ⁴ Small patient numbe ⁵ Several studies had p ⁶ Tisticons, as they did in J ⁶ Tisticons, as they did in J ⁷ Sudy hatted before c ⁷ Fine three studies in cl ⁸ Nonrandomized proce ⁸ None of the studies in cl ⁸ Nonrandomized proce ⁹ None of the studies in di- ⁹ To addition to the var ⁹ Pouro the studies funder funded by the manufa ⁶ Cone study on hermia.	, randon ominop studies, in Jon is in Jon in Jathe in Quality in Quality	mized controlled trials. because of lack of blindi blasty and breast surgery, regarding how long drai tes et al., ¹⁸ very high rate bias toward a no-drain F without drains. ¹⁸ mindium implant in th upph node dissection, whi art showed a statistically ed different definitions studies. ^{23,346,556,67} were funded by a manuf wree funded or a manuf wree funded or a manuf an progressive tensi ing studies (quiling). C ng and progressive tensi manufacturer ^{29,00,68,09} ant and a significant reduction hich may not be genera	ng. which may not be ger ins were kept in, ^{3,1+,6,20} to f seroma in Soon et odicy, as several authon e axilla, which may ha ch may not be general significant change in of low and high vacuu facturer of ultrasonic s treralizable to other pro- nomized design. Dong et al.'s surgical te ion sutures with exclu d several studies that m tion in seromas with surg n in seromas with surg	eralizable. (2021) al. ¹⁴ is kept patients is kept patients we affected serc izable to other izable to other m. m. calpels. ocedures. consignt find in ion with the in dures. ical-site immot	in the hospital u oma rate. ²⁸ procedures. ion with the inter ted a potential co nrandomized stu nave been fundeo tervention.	intil drains wer rvention, the n onfounder: sut dies shows the	e remov iajority (ure ligat t quilti	red. ^{5,24,28} Unclear w of the studies inclu of progressive ten (not disclosed). ^{27,62}	hether Boril ded had små ssels. ⁴⁸ sion sutures	e et al. used d ll numbers c reduced the	ompress f patient rate of s that are l	ion in patients with s and did not reach eroma significantly cnown to have been

Body Region and Strategy	RR of Seroma	þ	References
Head and neck			
Fibrin	0.16	0.04	67
Use of drains	1	1	12
Breast			
Use of drains	0.69	< 0.001	5, 13–15, 17, 19, 21
Volume-controlled drain removal	0.57	< 0.001	23–28
High drain vacuum	0.62	0.04	29-31
Sharp dissection	0.46	0.001	33, 37, 41
Ultrasonic dissection	0.61	< 0.001	32, 35, 36, 38, 40-43
PTS	0.41	< 0.001	26, 48, 50-52
Preventive use of sclerosant	2.9	0.002	54, 55
Fibrin	1	0.9	57, 60, 62–65, 69, 71
Postoperative immobilization	0.57	< 0.001	73–79
Postoperative compression	0.96	0.9	26
Back			
PTS	0.49	< 0.001	45-47, 49, 53
Fibrin	0.39	0.4	58, 70
Abdomen			,
Use of drains	0.75	0.18	6, 11, 16, 18, 20, 22
Clip/suture ligation of perforators	0.2	< 0.001	2
Scarpa fascia preservation	0.13	< 0.001	44
PTS	0.67	0.4	11
Fibrin	0.32	< 0.001	61,66
Talc	0.13	< 0.001	72
Postoperative compression	1	0.6	80
Sharp dissection	0.6	0.15	34, 39
Groin			,
Preventive use of sclerosant	1.2	0.44	56
Fibrin	0.88	0.9	68

RR, relative risk; PTS, progressive tension sutures.

a significant increase in the rate of seroma with the preventive use of sclerosant (56.8 percent versus 38.1 percent; p = 0.01; $l^2 = 67$ percent, indicating moderate heterogeneity), with a relative risk of 1.49 (95 percent CI, 1.07 to 2.07) (quality of evidence, very low; strength of recommendation, weak recommendation against the intervention).

Preventive Use of Fibrin and Thrombin

Fifteen randomized controlled trials including 872 patients analyzed the use of fibrin or thrombin versus control in a preventive manner during the initial surgical procedure (one in the head and neck, two in the abdomen, one in the groin, three in the back, and eight in the breast).⁵⁷⁻⁷¹ Three of those studies found a significant decrease in seroma formation with the preventive use of fibrin/thrombin. Considered in aggregate, there was a significant decrease in the rate of seroma with the use of fibrin/thrombin compared to control (15.9 percent versus 22.2 percent; p = 0.02; $I^2 < 0$, indicating low heterogeneity), with a relative risk of 0.72 (95 percent CI, 0.54 to 0.95) (quality of evidence, low; strength of recommendation, weak).

Preventive Use of Talc

One prospective comparative study including 180 patients analyzed the use of subcutaneous talc

in abdominal wall reconstruction.⁷² There was a significant decrease in postoperative seroma with the use of talc (2.7 percent versus 20.8 percent; p < 0.001), with a relative risk of 0.13 (95 percent CI, 0.03 to 0.54) (quality of evidence, very low; strength of recommendation, weak).

Postoperative Surgical-Site Immobilization

Seven randomized controlled trials including 575 patients analyzed postoperative surgical-site immobilization compared to early exercises, all in the setting of breast surgery.^{73–79} All seven studies compared free shoulder movement immediately postoperatively to limiting shoulder abduction and flexion for 5 to 12 days postoperatively (one study for 5 days, four studies for 7 days, one study for 10 days, and one study for 12 days). Four of those studies found a significant decrease in the rate of seroma with postoperative immobilization. Considered in aggregate, there was a significant decrease in the rate of seroma with postoperative immobilization (28.8 percent versus 50.5 percent; $p < 0.001; I^2 = 79$ percent, indicating high heterogeneity), with a relative risk of 0.57 (95 percent CI, 0.46 to 0.71). We did not find any difference in seroma rates depending on length of immobilization (quality of evidence, moderate; strength of recommendation, weak).

Postoperative Compression

Two randomized controlled trials including 157 patients analyzed postoperative compression of the surgical site (one in the breast and one in the abdomen).^{26,80} Neither study found a significant reduction in seroma formation with postoperative compression. Considered in aggregate, there was no reduction in the rate of seroma with compression (54.3 percent versus 55.3 percent; p = 0.9; P < 0 percent, indicating low heterogeneity), with a relative risk of 0.98 (95 percent CI, 0.74 to 1.31) (quality of evidence, very low; strength of recommendation, weak recommendation against the intervention).

DISCUSSION

Seroma is a common problem faced by plastic surgeons. It is the most common complication of latissimus dorsi muscle harvest,⁸¹ and a very common complication in postbariatric body contouring.^{82,83} Seroma avoidance has the potential to reduce patient morbidity, avoid subsequent procedures, and improve patient satisfaction. Previous systematic reviews on the topic were small, had conflicting findings, and did not analyze all potential strategies for seroma avoidance.^{84,85} Our goal with this study was to perform a comprehensive systematic review of all high-quality, Level I and II studies that have evaluated strategies for seroma avoidance.

We found that the use of closed-suction drains significantly reduces the incidence of seroma when dead space is created. Our finding agrees with previous studies that found that the use of closed-suction drains was beneficial in procedures with significant dead space formation, such as mastectomies^{86,87} and rhytidectomy,⁸⁸ but not in procedures without significant subcutaneous undermining, such as cesarean delivery.⁸⁹ In addition, we found that keeping drains in place until the daily output is lower than 20 to 50 cc/ day while the patient is ambulatory (volume-controlled drain removal) resulted in fewer seromas than removing drains on a certain, predetermined postoperative day regardless of drain output (time-controlled drain removal). This finding agrees with previous systematic reviews.⁹⁰ Moreover, our study found that higher drain vacuum (500 to 750 mmHg) results in fewer seromas than lower drain vacuum (100 to 250 mmHg). Our findings highlight not only the usefulness of inserting closed-suction drains any time dead space is created, but also the importance of meticulous drain stripping postoperatively to prevent clogging while maintaining high vacuum. It has

been previously shown that closed-suction drains should be stripped frequently,⁹¹ and that bulbs should be compressed side-to-side (rather than "bottom up") and emptied when 50 percent full,⁹² to maintain a high pressure gradient.

The nature and exact causes of postoperative seroma have been the subject of debate for several decades. Most of the research on this topic has been performed in the setting of axillary lymph node dissection for breast cancer. The hypothesis of many of those studies was that seroma accumulation was simply the result of lymph fluid leaking from transected lymphatic channels in the axilla.93 Studies evaluating the biochemical properties of seroma fluid, however, have demonstrated that seroma formation is a more complex process.^{29,94} Andrades et al. found that postabdominoplasty seroma fluid is an inflammatory exudate, whose composition is different from lymph fluid.¹¹ In fact, Klink et al. compared the characteristics of drainage from closed-suction drains in patients who went on to develop a seroma with the drainage characteristics in patients who did not develop a seroma.95 They found that drainage from the closed suction drain of patients who later developed a seroma had a significantly more inflammatory character, with a lower pH. These findings suggest that in addition to potential transudation from damaged lymphatic channels, there is exudation from inflamed tissues, and those two factors in combination may result in seroma formation.

Inflammation from shearing of tissues against each other seems to play a major role in seroma formation. One strategy to obliterate dead space and prevent shearing is the use of quilting and progressive tension sutures. Several retrospective studies have shown decreased drain output and very low seroma rates in abdominoplasty,^{1,96} abdominal wall reconstruction,⁹⁷ and latissimus dorsi muscle harvest^{98,99} with the use of progressive tension sutures. Our systematic review of prospective and randomized controlled trials has shown that the use of quilting sutures and progressive tension sutures is very effective at reducing the incidence of seromas.

Another strategy to reduce shearing forces is limiting postoperative surgical-site movement, which we found to be effective at reducing the incidence of seroma.¹⁰⁰ All of the included studies on this topic were on patients undergoing mastectomy and axillary lymph node dissection, where immobilizing the surgical site could be achieved by simply immobilizing the shoulder, without immobilizing the entire patient. This can be difficult to achieve in other plastic surgical procedures, where immobilizing the surgical site might require immobilizing the entire patient. In a retrospective study on patients undergoing abdominoplasty, Beer and Wallner found that bedrest for at least 48 hours resulted in significantly fewer seromas that ambulation after 24 hours.¹⁰¹ The inconvenience of immobilizing a patient, and the added risk of venous thromboembolism, must be weighed against the lower risk of seroma. With the advent of progressive tension sutures, the surgeon can now internally immobilize the surgical site without the need to immobilize the entire patient.

Fibrin sealant is commonly used after axillary lymph node dissection, the hypothesis being that fibrin can seal damaged lymphatic channels and cause tissue adhesion, thus decreasing shear. Previous studies on the usefulness of fibrin in seroma prevention have been widely contradictory. Our systematic review found that fibrin application at the end of surgery was effective at reducing the incidence of postoperative seroma. This is in contrast to previous smaller studies, which found no benefit to fibrin in breast surgery^{84,102} or in the latissimus dorsi donor site.^{85,103}

The inflammatory, exudative nature of seromas may also explain our finding that compression, whether in the form of an abdominal binder after abdominoplasty or a compression dressing after mastectomy, is ineffective at preventing seroma. This is an interesting finding, and has unclear implications on the treatment of established seromas: most clinicians initially treat seromas with aspiration and compression. It should be noted that we did not find any prospective studies on the role of compression in the treatment of established seromas.

Electrocautery has been shown to result in a pronounced postoperative inflammatory response. Yilmaz et al. found that the use of electrocautery resulted in significantly higher levels of inflammatory cytokines in the wound than sharp dissection and ultrasonic dissection.⁴¹ This likely explains our findings that electrocautery resulted in the highest incidence of seroma, followed by ultrasonic dissection and sharp dissection. This is in contrast to previous, smaller systematic reviews, which failed to demonstrate a difference.¹⁰⁴ Along the same line, we found that cautery ligation of blood vessels resulted in higher rates of seroma than clip/suture ligation. Some authors have attributed this finding to the fact that lymphatic channels often accompany blood vessels,¹⁰⁵ and that perforator clipping or suture ligation is an atraumatic way of controlling both vascular and

lymphatic structures, whereas the use of electrocautery likely induces an inflammatory reaction in the lymphatic channels. Interestingly, a previous systematic review found that deep inferior epigastric perforator (DIEP) donor sites had significantly lower rates of seroma than abdominoplasties.¹⁰⁶ The authors concluded that at least part of the difference was because of perforators most commonly being controlled with clips in DIEP flap harvest, compared with cautery in abdominoplasty, although others factors likely play a role, namely, a longer period of immobilization for DIEP flap recipients.

Sclerosants are commonly used for the treatment of established seromas. Those substances, which include tetracycline, doxycycline, and others, act by inducing inflammation, thus "roughing up" the capsule and allowing collapse of the seroma cavity. In contrast, we found that the prophylactic use of sclerosing substances during the initial surgical procedures resulted in a significant increase in seroma formation. This is consistent with the inflammatory nature of seromas. Sclerosant use at the initial operation seems to induce an undue inflammatory reaction, and should be avoided.

Yet another substance commonly used for seroma prevention is talc, which consists of hydrated magnesium silicate particles. Talc is commonly used in the treatment of pleural effusions,¹⁰⁷ and we found it to be effective at reducing the incidence of postsurgical seroma. Unlike sclerosing substances, it does not act by inducing inflammation.⁷² Its exact mechanism of action is unknown. One hypothesis is that it may act by "roughening" the tissue surface, thus reducing shear.⁷²

One effective strategy that was not included in our systematic review because of the lack of studies satisfying the inclusion criteria is the use of incisional negative-pressure wound therapy. One randomized controlled trial including 19 patients compared incisional negative-pressure wound therapy to standard surgical dressings in hip arthroplasty,¹⁰⁸ and found that the use of incisional negative-pressure wound therapy resulted in a significantly smaller volume of seroma (1.97 ml versus 5.08 ml; p = 0.02). This has been previously demonstrated in retrospective studies in abdominal wall reconstruction¹⁰⁹ and in an animal study by Kilpadi and Cunningham, who demonstrated that the mechanism by which incisional negative-pressure wound therapy reduced seroma formation was not direct suction of the seroma fluid into the sponge but increased clearance of fluid by the lymphatic system.¹¹⁰ This finding,

coupled with previous studies showing lower surgical-site infection rates when incisional negativepressure wound therapy was used on high-risk incisions,^{111–113} makes incisional negative-pressure wound therapy an excellent dressing for closed incisions at risk for seroma or infection.

We found that preservation of fat and Scarpa fascia during dissection for abdominoplasty resulted in fewer seromas than dissection directly on top of the musculofascia. This is in agreement with previous studies,¹¹⁴ and has been attributed to the possibility that preservation of the lymphatic channels in the sub-Scarpa fat compartment allows egress of fluid from the wound.⁴⁴ Another possibility may be that the smooth surface of the musculofascia is conducive to prolonged shearing against the skin flap, leading to inflammation and seroma.

Our systematic review analyzed only highquality data from Level I and II studies, which have less selection bias than lower level studies. By increasing the statistical power of those data, our systematic review has allowed us to identify significant differences in outcomes in certain cases where the original randomized controlled trials did not identify such differences. Our study has also allowed us to identify several deficiencies in the literature. We found only one randomized controlled trial and one prospective comparative study on the treatment of established seromas. Butler found that percutaneous seroma aspiration followed by fibrin instillation was more effective at preventing seroma reaccumulation than percutaneous aspiration alone.¹¹⁵ Taghizadeh et al. demonstrated that seroma aspiration and instillation of triamcinolone was more effective than aspiration alone.¹¹⁶ There are numerous case series reporting on the successful treatment of established seromas with percutaneous drainage,117 doxycycline,⁸³ erythromycin,¹¹⁸ talc,^{119,120} argon beam scarification,121 and surgical resection, with or without lymphatic mapping.¹²²⁻¹²⁴ However, we did not find any prospective studies evaluating the effectiveness of compression, percutaneous drain insertion versus percutaneous aspiration, or the instillation of other sclerosants.

Another strength of our study is that we included only studies that defined a seroma as a fluid collection evident on physical examination. We excluded studies that used imaging to diagnose seromas, as imaging has higher sensitivity than physical examination, and would obscure the results by overdiagnosing clinically significant seromas. Moreover, seroma that is detectable on physical examination is more clinically relevant than seroma detected on imaging. Studies that used imaging to diagnose seromas found small seromas in the majority of patients,¹⁰⁸ and therefore used "volume of seroma" as their endpoint, rather than "incidence of clinically relevant seroma," which is the endpoint of the studies included in this systematic review. One weakness of our study is the fact that several strategies for seroma prevention were evaluated by only one prospective study (e.g., method of vessel ligation, talc poudrage, and dissection plane in abdominoplasty). Thus, our systematic review was unable to augment the power of those existing studies. It should also be noted that optimal seroma prevention strategies likely differ from one body region to another, as noted in Table 2. In addition, the six studies evaluating time to drain removal used different drain outputs as endpoints, ranging from 20 to 50 cc/24 hours.

CONCLUSIONS

Our systematic review demonstrated that the incidence of postoperative seroma can be reduced by taking measures that obliterate dead space and reduce shear forces. When surgical dead space is created, closed-suction drains should be inserted, and careful postoperative drain care should be performed. The surgeon should consider the use of quilting or progressive tension sutures. Fibrin glue may be an alternative method of adhering the skin flap to the underlying tissue. Sharp dissection and careful control of vascular perforators should be undertaken whenever possible. Despite their potential usefulness in the treatment of established seromas, sclerosants have no role in seroma prevention. Consideration should be given to immobilizing the surgical site for a few days postoperatively. Surgical-site compression does not appear to play any role in seroma prevention. Further prospective comparative studies should be performed to better evaluate the best method of blood vessel ligation, the potential value of prophylactic subcutaneous talc, and the effectiveness of various methods for the treatment of established seromas.

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