Implant-based reconstruction is the most common reconstructive modality after mastectomy. This method of breast reconstruction may be done in patients in whom autologous options are not selected and has minimal morbidity and acceptable aesthetic results. However, many patients require radiation therapy (RT) in addition to mastectomy; this can negatively impact the success of implant-based breast reconstruction. Whether administered preoperatively or postoperatively, chest wall irradiation has been associated with an increased rate of complications.

**Background:** Use of the thoracodorsal artery perforator (TDAP) flap in combination with alloplastic devices has been proven to be a safe method of breast reconstruction. However, preoperative irradiation increases the complication rate and thus some consider preoperative radiotherapy a relative contraindication to alloplastic alone reconstruction. We evaluated the long-term outcomes of patients with preoperative radiotherapy who had delayed alloplastic reconstruction with a TDAP flap.

**Methods:** A retrospective analysis of a prospectively maintained database was performed to identify patients who had received a Latissimus Dorsi (LD), a Muscle Sparing Latissimus Dorsi (MSLD), or a TDAP flap plus a tissue expander or implant between 2005 and 2012. Information regarding patients’ primary diagnosis, radiation history, prior breast reconstructions, and complications was collected and analyzed.

**Results:** Sixteen patients who had a total of 16 breast reconstructions with an LD (6) or TDAP/MSLD1 flap (10). Demographic data, device type, co-morbidities and complications were analyzed. The rate of capsular contracture and size asymmetry were higher in the LD group, but there was no difference noted for major complications. Minor complications were also similar between the 2 groups.

**Conclusions:** Patients who underwent irradiation before TDAP flap did not have a higher complication rate when compared with patients who had a full LD flap following radiation. By integrating well-vascularized, nonradiated tissue of a TDAP flap in reconstruction, overall complication rate may be minimized and the results are comparable to the generally accepted method of utilizing the entire latissimus dorsi muscle.

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Jonathan Bank, MD*
Kelly Ledbetter, MD†
David H. Song, MD, MBA, FACS*

From the *Section of Plastic and Reconstructive Surgery, Department of Surgery, University of Chicago Medical Center, Chicago, Ill.; and †Division of Plastic Surgery, Department of Surgery, University of Washington, Seattle, Wash.

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In an effort to mitigate such complications, autologous flaps may be combined with the reconstruction to provide well-vascularized tissue above the implant to facilitate wound healing and soft-tissue expansion. Typically, the preferred flap to combine with an implant is the latissimus dorsi (LD) myocutaneous flap. The LD flap is a reliable flap that allows the mobilization of a large amount of muscle, subcutaneous fat, and skin. However, the LD flap is associated with donor-site seromas and hematomas, and reports have cited an overall complication rate of up to 30.4% and implant failure rate of 5.4%. Furthermore, by using the traditional method of LD flap interpolation, the entire muscle is sacrificed.

Recently, surgeons have begun to combine implant-based reconstruction with flaps that sacrifice less LD muscle. These flaps include the muscle-sparing latissimus dorsi (MSLD) flaps that were described by Hamdi et al9 in 2004 and the thoracodorsal artery perforator (TDAP) flap that was first described by Angrigiani et al10 in 1995. It is hypothesized that these flaps have the added benefit of preserving muscle strength, conserving contour, and decreasing postoperative pain and seroma formation. Both flaps have been proven safe when combined with tissue expanders (TEs) or implants for complete breast reconstruction.11,12

However, the effect of RT on TDAP or MSLD flaps remains unclear. This study evaluated the long-term outcomes of patients with preoperative radiotherapy who subsequently had a delayed reconstruction with pedicled LD flap, an MSLD flap, or a TDAP flap with expanders or implants all by the senior surgeon (D.H.S.).

METHODS

Study Design
We performed a retrospective chart review of a single surgeon’s prospectively maintained database of patients who had immediate or delayed breast reconstruction following a skin-sparing mastectomy for breast cancer between 2005 and 2012. Inclusion criteria were patients who had undergone RT, which either failed initial reconstruction, or had no prior attempt at reconstruction. All patients who received TEs or implants that were augmented by an LD, an MSLD type 1, or a TDAP flap were included in the study. Patients were excluded if they had partial breast reconstruction, incomplete medical records, or less than 3 months of follow-up. To maintain patient privacy, patients were assigned a unique identifier. Health Insurance Portability and Accountability Act regulations applied to this research and approval by the University of Chicago’s Institutional Review Board was established.

Collected data points included demographic data, smoking history, radiation history, body mass index, primary diagnosis, and history of prior breast reconstructions. Reconstructive data included timing of reconstruction, laterality, time to exchange, expander and implant type, and implant volume. Lastly, outcome data included capsular contracture using the modified Baker classification, infection, and implant exposure or extrusion.

Descriptive statistics of all demographic, reconstructive, and outcome data were reported as a mean or percentage of patients having a characteristic. Fisher’s exact test or the Student’s t test were used to statistically compare the rate of complications and complication types between the groups of patients who received preoperative radiotherapy and the groups of patients who did not receive preoperative radiotherapy. The significance level was set at P-value less than 0.05.

Preoperative Assessment
Indications for implant-based reconstruction with the addition of a TDAP, an MSLD, or an LD flap include failed prior implant-based reconstruction in the face of radiation or prior irradiation of the chest wall. For the first 2 years of the study period, the LD flap was the only flap performed. However, after 2007, the senior author utilized the algorithm presented by Hamdi et al9 in 2004 to determine the suitability of the TDAP, MSLD, or LD flap.

Surgical Technique
The flap is designed based on the location of potential perforators, the defect size, and the ability to close the donor site primarily. The skin island is centered on the perforators that are typically located 8 cm below the posterior axillary fold and 2 cm behind the anterior border of the LD muscle where the proximal skin perforator exits the muscle into the subcutaneous tissue. The precise perforator location is identified intraoperatively by pencil Doppler. Once designed, the flap is elevated from posterior to anterior just above the LD muscle fascia, and care is taken to capture the maximal amount of soft tissue (Fig. 1). The vascular pedicle is dissected to allow placement of the flap without tension. If a large-diameter (greater than 1 mm) pulsating perfo-

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rator is identified, a TDAP or an MSLD type 1 flap was performed. For a TDAP flap, the LD muscle is split and the perforator is dissected proximally until the origin from the subscapular vessels is identified. Alternatively, for an MSLD type 1 flap, a very small cuff of muscle was maintained around the perforators to prevent injuring the pedicle as it enters the flap in the previously irradiated patient if a distinct perforator was not readily identifiable. If there were multiple small, nonpulsatile perforators, then an MSLD type 2 flap was performed and up to 5 cm of muscle was harvested. Lastly, a standard LD flap was performed in the event that more muscle was needed and primarily was the historical experience of the senior author. All of the flaps provided a long vascular pedicle to allow sufficient interpolation. The flap is interpolated into the defect through a tunnel, secured in place, and the donor site closed (Fig. 2). The patient is then moved to a supine position to inset the flap and TE or implant in the subpectoral plane. The expander or implant is placed underneath the pectoralis muscle along with acellular dermal matrix regardless of the flap type. Expansion is initiated 2–3 weeks after surgery and was continued until appropriate volume was achieved. Subsequent to complete expansion, the patient then undergoes an outpatient exchange to a permanent silicone gel implant (Fig. 3).

RESULTS

A retrospective chart review identified 16 patients who had a total of 19 breast reconstructions with an LD (6) or TDAP/MSLD1 flap (10) following RT, between August 2005 and June 2012. Time from completion of RT in the LD group ranged from 1 to 20 years vs 4 to 66 months for the MSLD1/TDAP group. The mean body mass index was 27.11 ± 2.61 in the LD group and 21.73 ± 1.96 in the MSLD1/TDAP group; there were 2 smokers in the LD group and none in the MSLD1/TDAP group; and there was 1 diabetic patient in each group. Table 1 details patient characteristics of each group.

Three of the LD patients had direct-to-implant reconstruction; the remainder of patients had staged reconstruction with expanders. Reconstructions were performed in a delayed fashion or following prior failed reconstruction. Two (33.33%) of the LD procedures were performed as the initial reconstruction, whereas 4 (66.67%) were performed after failure of an implant-based reconstruction without supplemental autogenous tissue. The MSLD1/TDAP group contained 8 patients (80%) who were reconstructed by this method as the primary modality; 2 (20%) were salvage cases.

Mean follow-up time from the flap with expander (or implant) procedure was 24.33 ± 17.09 months in the LD group vs 11.9 ± 10.67 in the MSLD1/TDAP group. All flaps survived. Expander loss occurred in one of the MSLD1/TDAP patients. The rate of capsular contracture and size asymmetry was higher in the LD group, but there was no statistical difference noted for any of the complications (Table 2). The overall rate of major complications (implant loss, wound break down, and grade III or IV capsular contracture) in the LD group was 33.33% vs 10% in the MSLD1/TDAP group, with no statistical difference ($P > 0.05$, Table 2). There was no difference between the 2 groups with regard to the rate of minor complications including seroma at the reconstructed breast site, perceived “tightness” of the reconstructed breast, breast asymmetry, implant malposition, and other minor complications such as minor infections. No patients developed a donor-site seroma or required evacuation of a hematoma.
DISCUSSION

After a mastectomy, alloplastic reconstruction is the most common form of breast reconstruction due to its minimal morbidity and acceptable aesthetic results. Additionally, it may be done in patients whose comorbidities make autologous reconstruction risky. Up to 75–88% of patients grade their overall aesthetic result as good, very good, or excellent. Adjuvant RT is a mainstay in the treatment of stage II and node-positive breast cancer in pre- and postmenopausal women as it can decrease local recurrence from 23% to 6% and improve patient survival.

However, RT has deleterious effects on local tissue and can negatively impact the success of alloplastic breast reconstruction, in both the adjuvant and neoadjuvant settings. Overall complications are higher in comparison to the nonirradiated reconstructions, manifesting in implant extrusion, capsular contractions, and inferior aesthetic results.

In an effort to mitigate such complications, surgeons frequently attempt to provide additional support at the inferior pole of the implant and decrease the tension across the incision. This may be done with the addition of an autologous flap to provide pliable, well-vascularized tissue above the implant to facilitate wound healing and soft-tissue expansion. The LD flap is most commonly employed in salvage of a radiated implant reconstruction or prophylactically in high-risk cases. Although the success rate with this modality is high, the harvest of this large myocutaneous flap has inherent disadvantages, with reported weakness, contour deformity, and increased risk of seromas and hematomas. Similar to patients who undergo implant-only reconstruction, many of the patients who receive an LD flap plus an implant still require reoperation for change or removal of the prosthesis.

A study published in 2012 demonstrated that in the face of prior irradiation, patients who had implant-based reconstruction with a LD flap still had an overall complication rate of 30.4% and implant failure rate of 5.4%. In the radiated cohort of our study population, the rate of major complications (implant loss, wound breakdown, and grade III or IV capsular contracture) in the group of irradiated patients treated with TDAP or MSLD type 1 flaps was 10%. There was 1 implant extrusion in the radiated group (10%). While these complication rates

Fig. 3. Preoperative (A–C) and postoperative views (D–F) following thoracodorsal artery perforator flap in a radiated patient. Note the concealed donor-site scar and the preservation of chest contour.
are not significantly lower than those published in the largest series to date,\(^8\) we contend that the TDAP or MSLD type 1 techniques are not inferior to the LD flap in the irradiated patient and indeed can be seen as equivalent. Although dissecting the TDAPs is technically demanding and possibly more time consuming, one does not sacrifice the entire LD muscle and possible benefits of lower seroma rates in the donor site may be realized. Regardless of the flap used, the expander or implant is placed underneath the pectoralis muscle along with acellular dermal matrix. While not specifically assessing this factor in our study, we believe that with revascularization, the coverage of expanders and ultimately implants allows for a softer reconstruction and mitigates against palpable capsular contracture. The ADM further allows for facility in expansion given the irradiated pectoralis muscle.

Limitations of this study include the small sample size and the retrospective nature of the investigation. Furthermore, this study did not evaluate the benefits of preserving the LD muscle with regard to objective and measured upper extremity function and aesthetic evaluation of scarring and contour deformities. Precise analysis of operative time was not performed.

Despite these shortcomings, this is the first study that examined the effects of irradiation on implant-based breast reconstruction with a TDAP or an MSLD type 1 flap. We found that the pedicled LD, MSLD type 1, or TDAP flap can be used with TEs or implants to successfully reconstruct breasts in patients regardless of their radiation status. Although preoperative RT increased the overall complication rate in the TDAP group vs the LD group, it did not increase the risk of implant loss. The rate of complications was not significantly different between the LD and TDAP flaps. Therefore, we conclude that the TDAP flap is not inferior to an LD flap when used for implant-based reconstruction in the presence of RT.

### CONCLUSION

In the face of previous irradiation, the TDAP flap is equivalent to a full muscle LD flap when used to augment alloplastic breast reconstruction.

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**Table 1. Patient characteristics**

|                      | LD        | MSLD1/TDAP | P     |
|----------------------|-----------|------------|-------|
| No. procedures       | 6         | 10         |       |
| Age                  | 46.85 ± 5.41 | 41.00 ± 7.26 | 0.67  |
| Average BMI          | 27.11 ± 2.61 | 21.73 ± 1.96 | 0.99  |
| Race                 |           |            |       |
| White                | 3 (50%)   | 8 (80%)    | 0.26  |
| African American     | 3 (50%)   | 1 (10%)    |       |
| Other                | 0 (0%)    | 1 (10%)    | 1     |
| Smoker               | 2 (33.33%)| 0 (0%)     | 0.08  |
| Diabetes             | 1 (16.67%)| 1 (10%)    | 1     |
| Range time between completion of preoperative RT and reconstruction (mo) | 12–240 | 4–66 |       |
| Average time between completion of preoperative RT and reconstruction (mo) | 82.83 | 11.50 | 0.025 |
| Follow-up (mo)       | 24.33 ± 17.09 | 11.9 ± 10.67 | 0.11  |
| No. expanders        | 3 (50%)   | 10 (100%)  | 0.07  |
| Average final fill volume (ml) | 483.33 | 388.89 |       |
| No. direct to implant | 3 (50%)  | 0 (0%)     |       |
| Average implant size (ml) | 225    |          |       |
| Delayed initial reconstruction | 2 (33.33%) | 8 (80%) | 0.13  |
| Failed prior reconstruction | 4 (66.67%) | 2 (20%)  | 0.13  |

**Table 2. Complications**

|                      | LD        | MSLD1/TDAP | P     |
|----------------------|-----------|------------|-------|
| Major complications  |           |            |       |
| Implant loss         | 0 (0%)    | 1 (10%)    | 1     |
| Wound breakdown      | 0 (0%)    | 0 (0%)     | 1     |
| Capsular contracture | 2 (33.33%)| 0 (0%)     | 0.2219|
| Minor complications  |           |            |       |
| Seroma               | 0 (0%)    | 1 (10%)    | 1     |
| “Tightness”          | 0 (0%)    | 1 (10%)    | 1     |
| Size asymmetry       | 4 (66.67%)| 3 (30%)    | 0.13  |
| Implant malposition  | 0 (0%)    | 1 (10%)    | 1     |
| Other                | 1 (7.14%) | 2 (20%)    | 1     |

BMI, body mass index; LD, latissimus dorsi myocutaneous flap; MSLD1, muscle-sparing latissimus dorsi myocutaneous flap type 1; RT = radiation therapy, TDAP, thoracodorsal artery perforator flap.
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