Revision Incidence after Immediate Direct-to-Implant versus Two-Stage Implant-Based Breast Reconstruction Using National Real-World Data

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Background: In immediate implant-based breast reconstruction (IBBR), large variation is observed in current practices between a direct-to-implant and a two-stage approach (insertion of a breast implant after a tissue expander). This population-based study aimed to compare unplanned short- and long-term revision incidence between direct-to-implant and two-stage IBBR in The Netherlands.

Methods: All patients who underwent immediate IBBR following a mastectomy between 2015 and 2019 were selected from the nationwide Dutch Breast Implant Registry. Short- and long-term unplanned revision incidences were studied per immediate IBBR, including revision indications and the total number of additional operations. Confounding by indication was limited using propensity score matching.

Results: A total of 4512 breast implants (3948 women) were included, of which 2100 (47%) were for direct-to-implant IBBR and 2412 (53%) were for two-stage IBBR. Median (IQR) follow-up was 29 months (range, 16 to 45 months) and 33 months (range, 21 to 47 months), respectively. Short-term revision incidence was 4.0% and 11.7%, respectively (conditional OR, 0.31; 95% CI, 0.23 to 0.42%). Long-term revision incidence was 10.6% (95% CI, 9.2 to 12.1%) and 16.4% (95% CI, 14.8 to 17.9%), respectively. In the propensity score–matched cohort, similar results were found. In the direct-to-implant group, more breasts were reconstructed within the planned number of operations than in the two-stage group.

Conclusions: Unplanned revision surgery occurred less often after direct-to-implant IBBR, and more breasts were reconstructed within the planned number of operations compared to two-stage IBBR. These results, based on real-world data, are important for improving patient counseling and shared decision-making. *(Plast. Reconstr. Surg.* 151: 693, 2023.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Risk, II.

Immediate postmastectomy breast reconstruction is becoming increasingly popular, with up to 50% of mastectomy patients undergoing this type of reconstruction in current practice.[1,2] Although autologous techniques are increasingly

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being used, immediate implant-based breast reconstruction (IBBR) is still most often performed (70% to 90%).[1–5] Immediate IBBR can be achieved using either a one-stage direct-to-implant approach or a two-stage technique with a tissue expander (TE), which is replaced by a definite breast implant during a second operation.

There is an ongoing debate about the differences in complications and cosmetic outcomes between direct-to-implant and two-stage breast reconstruction, as direct comparisons in randomized controlled trials (RCTs) have not been performed.[6–9] Second, not all patients are eligible for both reconstruction techniques, resulting in a selection bias. Possible advantages of direct-to-implant IBBR include fewer outpatient clinic visits and fewer operations, expected lower overall costs, and a quicker return to the patient's social and working life.[10,11] Possible disadvantages are difficulties in using implant sizes larger than the original breast(s), higher probability of asymmetry, and the potentially higher risk of adverse events, especially if acellular dermal matrices (ADMs) or meshes are used.[12,13]

The latest evidence-based Dutch guideline for breast reconstruction from 2015 states that it is difficult to make evidence-based recommendations because of a lack of high-quality evidence.[14] This lack of high-quality evidence may contribute to unwanted variation in current practices among health care providers. These arguments emphasize the need for a better understanding of the differences in risks and outcomes to improve patient counseling and quality of care. Therefore, this study aimed to compare revision incidence, revision indications, and the additional number of operations per breast between direct-to-implant and two-stage IBBR in a nationwide, population-based cohort using the Dutch Breast Implant Registry (DBIR).

METHODS

Design and Study Population

This observational cohort study included all women who had been prospectively registered in the DBIR after undergoing a direct-to-implant or two-stage immediate IBBR between January 1, 2015, and December 31, 2019. Indications for an immediate IBBR were mastectomy for breast cancer or prophylactic mastectomy.

Patients who had undergone reconstruction for a benign condition, who had undergone any previous breast implant surgery, and in whom additional surgical techniques (fat grafting, mastopexy, or autologous flap cover) had been used during implant insertion, were excluded from analysis. Of the women with a planned two-stage IBBR, information on both the first stage (tissue expander insertion) and second stage (tissue expander exchange for permanent breast implant) was necessary for inclusion.

Data Collection: The DBIR

The DBIR is a nationwide, population-based registry. Since 2015, patient, surgery, and implant characteristics have been prospectively collected for all patients undergoing breast implant surgery in The Netherlands for breast reconstruction or breast augmentation. All operations that concern implant insertion, repositioning, replacement, or explantation have to be registered. More details about the registry have been described previously.[1,15,16] Currently, 74 of the hospitals (100%) and 37 of the private clinics (95%) where breast implant surgery is being performed are included in the DBIR. For the current study, the last data update was on May 8, 2020.

Definitions

Direct-to-implant IBBR was defined as the insertion of a permanent breast implant during the same operation as the mastectomy. Two-stage IBBR was defined as the insertion of a tissue expander (TE) during the same operation as the mastectomy, followed by a second operation in which a permanent breast implant replaced the TE.

Completion of each reconstruction trajectory was defined as the moment a permanent breast implant was inserted. The reconstruction trajectory of a two-stage IBBR was defined as the time between mastectomy with immediate TE insertion and TE replacement with a permanent breast implant. Revision surgery was defined as the first unplanned reoperation after insertion, in which the breast implant or TE was repositioned, explanted, or replaced. Indications for an unplanned revision were mastectomy skin flap necrosis, skin scarring problems, autologous flap problems, deep wound infections, seroma or hematoma, capsular contracture, newly diagnosed breast cancer, breast implant-associated anaplastic large cell lymphoma, breast pain, asymmetry, dissatisfaction with volume, patient-requested implant removal because of nonspecific health symptoms, device malposition, and device rupture or deflation.

Exact definitions of all patient, surgery, revision, and implant variables used for analysis can be found in the DBIR Data Dictionary. (**See Appendix, Supplemental Digital Content 1**, which

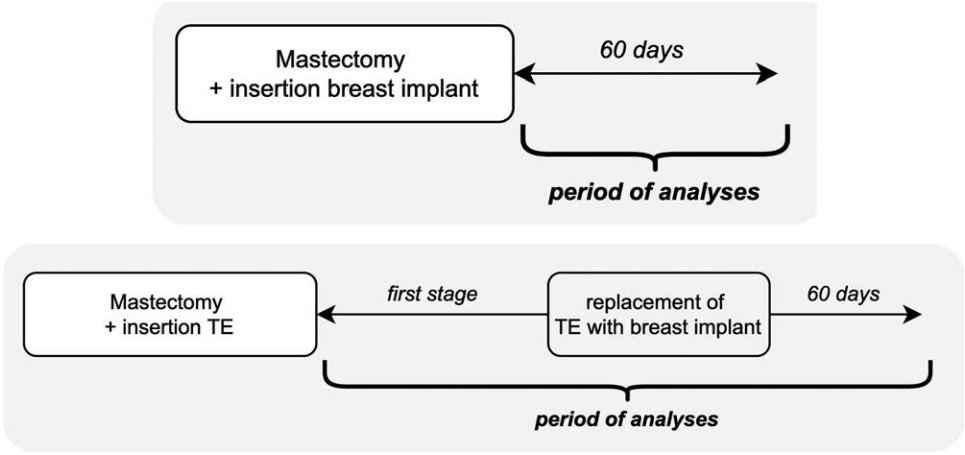

Fig. 1. Schematic view of the two analyzed reconstruction trajectories: from mastectomy and immediate IBBR until 60 days after completion of the reconstruction. (*Above*) Reconstruction trajectory of direct-to-implant IBBR. (*Below*) Reconstruction trajectory of two-stage IBBR.

shows the DBIR Data Dictionary, ***http://links.lww.com/PRS/F662***.)

Outcome Measures

The primary outcome was the short-term revision incidence of both IBBR techniques during the time from mastectomy until 60 days after the last planned operation in each reconstruction trajectory (Fig. 1). A time interval of 60 days was chosen because a substantial number of complications in breast implant surgery occur after 30 days.[17,18] Subsequently, the long-term cumulative revision incidence within 2 years after mastectomy, revision indications, and the total number of additional operations per breast were evaluated for both IBBR techniques. Potential confounding factors were identified based on existing literature and clinical rationale. A directed acyclic graph was used to visualize this process before performing analyses.[19]

Statistical Analysis

All analyses were performed with the implant as the unit of analysis, using R software, version 1.4.1106-2009-2021 (RStudio, Inc.). Missing data patterns were evaluated, resulting in the assumption of data being missing at random. Multiple imputation by chained equations was performed (mice package, version 3.13.0).[20,21] The outcome variable itself was not imputed. Statistical models were fitted and results were pooled following the Rubin rules.[22] (**See Table, Supplemental Digital Content 2**, which shows raw data of patient and surgery characteristics at the time of mastectomy and immediate IBBR, ***http://links.lww.com/PRS/F663***.)

Baseline characteristics were compared between groups using t tests, Mann-Whitney U tests, chi-square tests, or Fisher exact tests accordingly. A two-sided value of $P < 0.050$ was considered statistically significant.

To assess the likelihood of short-term revision, multivariable logistic regression analyses were performed (Stats package, version 4.0.2). Subsequently, to account for clustering of patients and implants within health care institutions that were likely to be correlated with practices performed, a conditional odds ratio with 95% confidence interval was calculated using a mixed-effects logistic regression model (lme4 package, version 1.1-26). In this mixed-effects model, confounding factors that were distributed differently between the revision and no-revision groups were entered as fixed effects, and health care institutions were included as random intercepts.

The crude, long-term cumulative revision incidence was calculated using Nelson-Aalen estimates. Implants without any revision at closure of the data set on May 8, 2020, were censored. Ideally, a hazard ratio would be calculated using a Cox proportional hazards model, but only if the proportional hazard assumption was met.

Sensitivity Analysis

Two sensitivity analyses were performed. First, the E-value was calculated (EValue package, version 4.1.2). An E-value assesses the minimum strength an unmeasured confounding factor must have, to negate the observed treatment-outcome

association.[23] Second, propensity score matching (PSM) was used to mimic pseudorandomization and assess the likelihood of short- and long-term revision. By using PSM, potential confounding by indication is limited.[24,25] Subsequently, a logistic regression model was used to calculate the propensity score for undergoing direct-to-implant IBBR using all preoperative covariates: age, American Society of Anesthesiologists classification, body mass index, smoking status, previous radiotherapy, postoperative radiotherapy planned, year of surgery, health care institution, health care institution volume, reconstruction indication, and laterality. In the PSM analyses, records with any missing preoperative characteristic were excluded. Matching was performed using a 1:1 ratio with a caliper width of 0.2 times the standard deviation of the logit (MatchIt package, version 4.1.0). Potential imbalances before and after matching were assessed using standardized mean differences.[26] A baseline characteristic with a standardized mean differences of 10% or more was considered imbalanced between the direct-to-implant and two-stage group.

RESULTS

A total of 3948 patients and 4512 breast implants met the inclusion criteria. (**See Figure, Supplemental Digital Content 3**, which shows a flowchart of implant selection. *More than one additional surgery technique could be registered per record, ***http://links.lww.com/PRS/F664***.) A total of 3710 patients (94.0%) underwent immediate IBBR after mastectomy for breast cancer and 238 (6.0%) after prophylactic mastectomy. These reconstructions were performed in 75 health care institutions with a mean volume per institution of 111 breast implant operations per year (range, 13 to 546).

A total of 2100 breast implants (46.5%) were inserted for a direct-to-implant IBBR, and 2412 TEs (53.5%) were inserted for a two-stage IBBR. Direct-to-implant IBBR was more frequently performed in younger, nonsmoking patients; if postoperative radiotherapy was planned; in bilateral procedures; in case of nipple-sparing surgery; with partial pectoralis major coverage; when using fewer infection control measures; with the use of an ADM/mesh, in more recent years; and in health care institutions with a volume of more than 200 implant operations per year. (**See Table, Supplemental Digital Content 4**, which shows patient and surgery characteristics at the time of mastectomy and immediate IBBR per reconstruction trajectory, ***http://links.lww.com/PRS/F665***.)

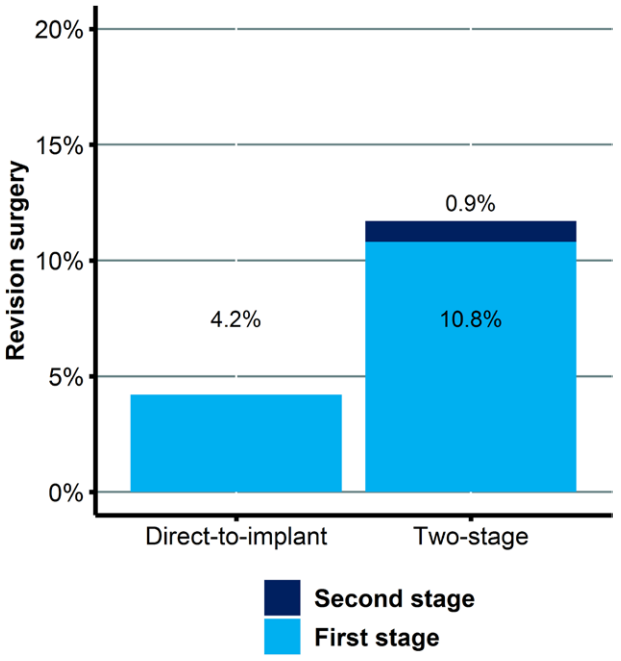

Fig. 2. Short-term (≤60 days) revision incidence per breast reconstruction trajectory.

Short-Term Revision Incidence

Of 2100 breast implants inserted during direct-to-implant IBBR, 84 (4.0%) underwent unplanned revision surgery within 60 days after insertion of the breast implant. Of 2412 breasts that underwent two-stage IBBR, 281 (11.7%) had an unplanned revision within 60 days after completion of the entire reconstruction trajectory. The majority of these unplanned revisions occurred during the first stage of a two-stage reconstruction ($n = 259$) (Fig. 2).

Revision surgery was more frequently observed after two-stage IBBR, in patients with older age, in patients with higher American Society of Anesthesiologists classification and body mass index, in patients who smoked, in middle-volume health care institutions (50 to 200 implant operations per year), after non–nipple-sparing surgery, if the implant was not completely covered with pectoralis major, and if an ADM/mesh was used (Table 1). Implants inserted during a direct-to-implant procedure had a lower likelihood of short-term revision surgery compared with a two-stage procedure (unadjusted OR, 0.32; 95% CI, 0.25 to 0.41; adjusted OR, 0.27; 95% CI, 0.20 to 0.36; conditional OR, 0.31; 95% CI, 0.23 to 0.42) (Table 2).

Long-Term Revision Incidence

The median (interquartile range [IQR]) follow-up time was 29 months (IQR, 16 to 45 months) in the direct-to-implant group and 33

Table 1. Patient and Surgery Factors at the Time of Mastectomy and Immediate IBBR, per Group with and without Short-Term (≤60 Days) Revision Surgery after Completion of the Reconstruction Trajectory

	Total Group (%)	No Short-Term Revision (%)	Short-Term Revision (%)	*P*
No.	4512	4147 (91.9)	365 (8.1)	
Intervention of interest				
Type of IBBR				<0.001
Direct-to-implant	2100 (46.5)	2016 (48.6)	84 (23.0)	
Two-stage	2588 (53.5)	2131 (51.4)	281 (77.0)	
Patient characteristics				
Mean age ± SD, yr	49.0 ± 11.3	48.8 ± 11.3	51.0 ± 10.5	<0.001
ASA classification				<0.001
I	2878 (63.8)	2694 (65.0)	184 (50.4)	
II	1500 (33.2)	1338 (32.3)	162 (44.4)	
III+	134 (3.0)	115 (2.7)	19 (5.2)	
BMI, kg/m^2				<0.001
Median	23.0	22.9	24.6	
IQR	20.5–25.8	20.4–25.5	22.1–28.1	
Smoking status				<0.001
Not smoking	3852 (85.4)	3567 (86.0)	285 (78.1)	
Smoking	660 (14.6)	580 (14.0)	80 (21.9)	
Previous radiotherapy				0.118
No	4297 (95.2)	3956 (95.4)	341 (93.4)	
Yes	215 (4.8)	191 (4.6)	24 (6.6)	
Surgery characteristics				
Health care institution volume (per year)				0.003
<50 implant operations	506 (11.2)	463 (11.2)	43 (11.8)	
50–99 implant operations	783 (17.4)	702 (16.9)	81 (22.2)	
100–200 implant operations	1824 (40.4)	1667 (40.2)	157 (43.0)	
>200 implant operations	1399 (31.0)	1315 (31.7)	84 (23.0)	
Reconstruction indication				0.897
Breast cancer	4094 (90.7)	3764 (90.8)	330 (90.4)	
Prophylactic mastectomy	418 (9.3)	383 (9.2)	35 (9.6)	
Laterality				0.291
Unilateral	2933 (65.0)	2686 (64.8)	247 (67.7)	
Bilateral	1579 (35.0)	1461 (35.2)	118 (32.3)	
Incision site				0.043
Nipple-sparing	1035 (22.9)	966 (23.3)	69 (18.9)	
Non–nipple-sparing	3193 (70.8)	2914 (70.3)	279 (76.4)	
Other	284 (6.3)	267 (6.4)	17 (4.7)	
Plane				0.001
Completely covered with PM muscle	2490 (55.2)	2314 (55.8)	176 (48.2)	
Partially covered with PM muscle	1848 (41.0)	1684 (40.6)	164 (44.9)	
Other	174 (3.8)	149 (3.6)	25 (6.9)	
No. of applied ICMs during implant insertion				0.121
<4	910 (20.2)	845 (20.4)	65 (17.8)	
4	1557 (34.5)	1441 (34.7)	116 (31.8)	
>4	2045 (45.3)	1861 (44.9)	184 (50.4)	
ADM/mesh				0.028
No	4045 (89.6)	3705 (89.3)	340 (93.2)	
Yes	467 (10.4)	442 (10.7)	25 (6.8)	

ASA, American Society of Anesthesiologists; PM, pectoralis major; ICMs, infection-control measures.

months (IQR, 21 to 47 months) in the two-stage group. After direct-to-implant IBBR, the crude cumulative unplanned revision incidence within 2 years was 10.6% (n = 220; 95% CI, 9.2 to 12.1%). Within the two-stage group, this was 16.4% (n = 406; 95% CI, 14.8 to 17.9%) (Fig. 3, *above*). A hazard ratio was not calculated, because the proportional hazard assumption was not met.

Table 2. Likelihood of Short-Term Revision Surgery after Completion of the Reconstruction Trajectory[a]

	OR (95% CI)
Unadjusted (univariable logistic regression model)	
Two-stage	1 (Ref)
Direct-to-implant	0.32 (0.25–0.41)
Adjusted (multivariable logistic regression model)	
Age	0.32 (0.25–0.42)
Age and ASA	0.32 (0.25–0.41)
Age, ASA, and BMI	0.32 (0.25–0.41)
Age, ASA, BMI, and smoking	0.32 (0.25–0.42)
Age, ASA, BMI, smoking, and institution volume	0.33 (0.25–0.43)
Age, ASA, BMI, smoking, institution volume, and incision site	0.33 (0.25–0.43)
Age, ASA, BMI, smoking, institution volume, incision site, and plane	0.27 (0.20–0.35)
Age, ASA, BMI, smoking, institution volume, incision site, plane, and ADM/mesh	0.27 (0.20–0.36)
Conditional (mixed-effects logistic regression model)	
Age, ASA, BMI, smoking, institution volume, incision site, plane, ADM/mesh, and health care institution[b]	0.31 (0.23–0.42)

Ref, reference; ASA, American Society of Anesthesiologists; BMI, body mass index.
[a]Direct-to-implant IBBR (n = 2100 implants), and two-stage IBBR (n = 2412 implants).
[b]The conditional OR was obtained by entering age, ASA classification, BMI, smoking, institution volume, incision site, plane, and ADM/mesh as fixed effects into the model, and health care institution as random effect.

Revision Indications

Within 60 days after direct-to-implant IBBR, the most frequently registered revision indications were mastectomy skin flap necrosis and deep wound infections (Table 3). After 60 days, asymmetry, breast pain, and dissatisfaction with volume were most frequently observed.

During the complete first stage of a two-stage IBBR, revision surgery was mostly performed for deep wound infections and seroma or hematoma. Within 60 days of the second stage of two-stage IBBR, the majority of revisions were for seroma or hematoma, deep wound infections, and skin scarring problems. Over the longer term, asymmetry, breast pain, capsular contracture, and dissatisfaction with volume were mostly observed.

Very few implants were removed on patients' request because of nonspecific health symptoms. No implant removals for BIA-ALCL were registered.

Additional Operations

During the follow-up period, 1880 of 2100 breasts (89.5%) in the direct-to-implant IBBR cohort were reconstructed within one operation. Seventy-seven breasts (3.7%) needed one, 106 (5.0%) needed two, and 37 (1.8%) needed three or more additional operations.

In the two-stage IBBR group, 2006 of 2412 breasts (83.2%) were reconstructed within the planned two procedures. One hundred sixty-seven breasts (6.8%) needed one, 74 (3.1%) needed two, and 81 (3.4%) needed three or more additional operations. Eighty-four breasts (3.5%) needed revision surgery right after TE insertion and did not reach the second stage within the median follow-up.

Sensitivity Analysis

For the conditional OR of short-term revision surgery, the E-value was 5.9. This indicates that residual confounding could explain the observed association if an unidentified confounding factor exists with a relative risk association of at least 5.9. The E-value for the adjusted hazard ratio of long-term revision surgery was not calculated because the proportional hazard assumption was not met.

After limiting confounding by indication using propensity score matching, the matched cohort included 646 records, of which 323 (50.0%) were direct-to-implant records and 323 (50.0%) were two-stage records. Although before matching, an imbalance in preoperative baseline characteristics was observed, no imbalances were observed after matching. (**See Table, Supplemental Digital Content 5**, which shows preoperative patient and surgery characteristics at the time of mastectomy and immediate IBBR, per reconstruction trajectory, before and after propensity score matching, ***http://links.lww.com/PRS/F666***.) In the matched cohort, implants inserted during direct-to-implant IBBR had a lower conditional likelihood of short-term revision compared to a two-stage procedure (conditional OR, 0.36; 95% CI, 0.21 to 0.60). For the long-term, risk of revision surgery was 32% lower for implants inserted during direct-to-implant IBBR compared to two-stage IBBR (hazard ratio, 0.68; 95% CI, 0.46 to 0.99). The crude cumulative revision incidence at 2 years was 15.4% (95% CI, 10.8 to 19.9%) after direct-to-implant IBBR and 22.9% (95% CI, 17.4 to 28.0%) after two-stage IBBR (Fig. 3, *below*).

DISCUSSION

This nationwide population-based study included close to 100% of all health care institutions performing breast reconstruction in The Netherlands. After adjusting for confounders and

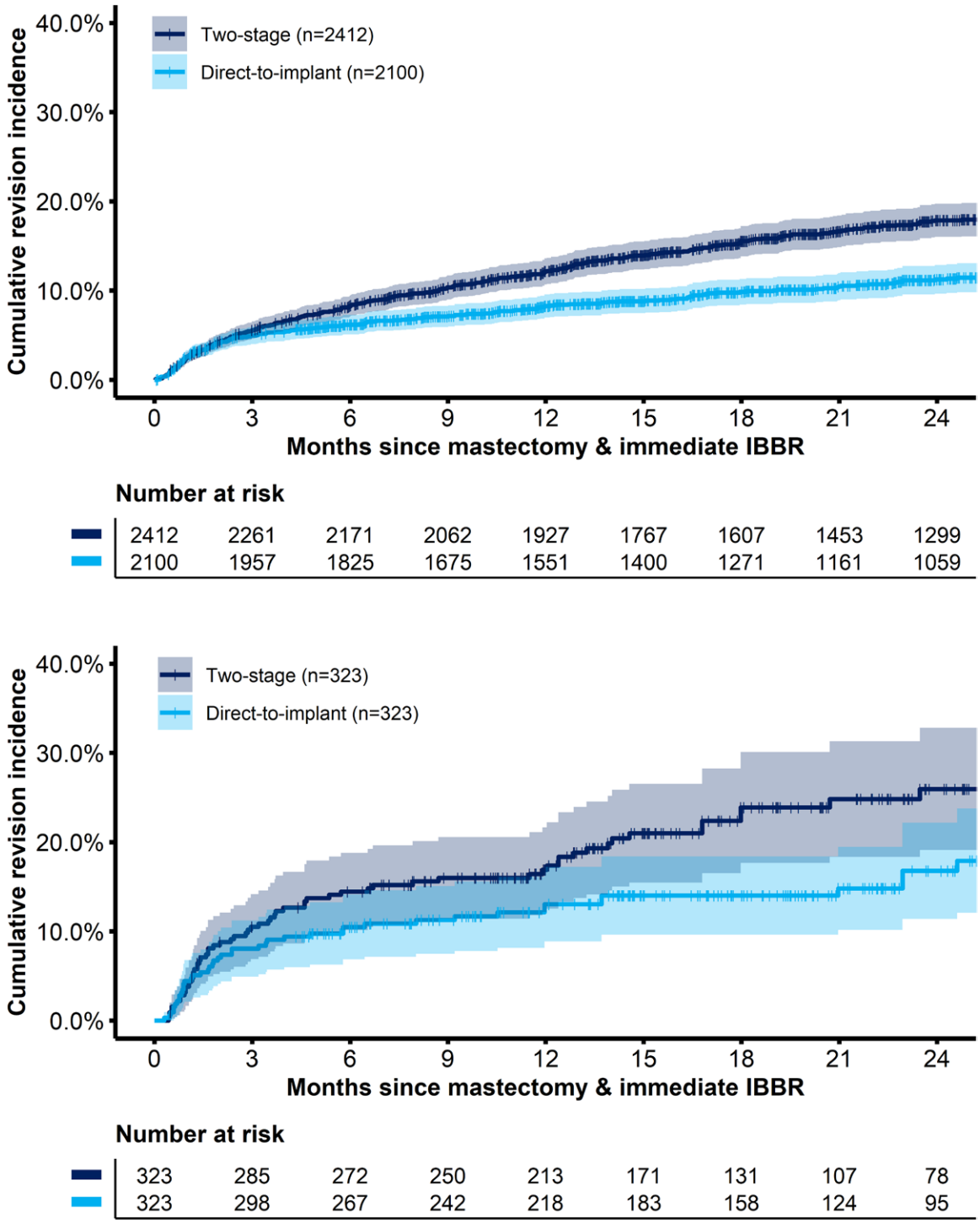

Fig. 3. Crude, long-term cumulative revision incidence after mastectomy and immediate direct-to-implant IBBR or immediate two-stage IBBR. (*Above*) In the complete cohort. (*Below*) In the matched cohort (sensitivity analysis). Curve includes revisions during the first and second stages of the reconstruction trajectory.

variation between centers, direct-to-implant IBBR was associated with a lower short-term and long-term unplanned revision incidence than two-stage IBBR. After limiting confounding by indication, comparable results were found. In addition, in the direct-to-implant group, more breasts were reconstructed within the planned number of operations than in the two-stage group.

Interestingly, both Basta et al. and Lee and Mun reported in their meta-analysis that direct-to-implant

Table 3. Indications for Short- and Long-Term Revision Surgery per Reconstruction Trajectory[a]

	Direct-to-Implant IBBR (%)		Two-Stage IBBR (%)		
	Short-Term (≤60 Days)	Long-Term (>60 Days)	During Complete First Stage	Short-Term (≤60 Days Second Stage)	Long-Term (>60 Days Second Stage)
No.	84	136	259	22	125
Deep wound infection	36 (43)	17 (13)	108 (42)	6 (26)	7 (6)
Seroma or hematoma	13 (16)	17 (13)	59 (23)	10 (46)	9 (7)
Mastectomy skin flap necrosis	45 (54)	14 (10)	44 (17)	1 (5)	4 (3)
Asymmetry	2 (2)	50 (37)	18 (7)	2 (9)	46 (37)
Breast pain	7 (8)	32 (24)	33 (13)	2 (9)	35 (28)
Capsular contracture	1 (1)	22 (16)	33 (13)	0 (0)	32 (26)
Skin scarring problems	11 (13)	5 (4)	28 (11)	5 (23)	10 (8)
Dissatisfaction with volume	2 (2)	29 (21)	8 (3)	1 (4)	28 (22)
Device malposition	2 (2)	25 (18)	16 (6)	0 (0)	24 (19)
Device rupture or deflation	2 (2)	9 (7)	43 (17)	1 (5)	5 (4)
Newly diagnosed breast cancer	5 (6)	10 (7)	10 (4)	1 (5)	1 (1)
Patient-requested implant removal because of nonspecific health symptoms	1 (1)	3 (2)	1 (<1)	0 (0)	1 (1)
BIA-ALCL	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

BIA-ALCL, breast implant-associated anaplastic large cell lymphoma.
[a]Multiple indications could be reported per revision procedure.

procedures were associated with a 1.24 (95% CI, 1.02 to 1.53) and 1.25 (95% CI, 0.40 to 3.89) higher likelihood of revision surgery, respectively, although the latter result was not statistically significant[8,9] However, both meta-analyses included mainly single-center studies, with low numbers of reconstructions, high heterogeneity in follow-up time, and without adjusting for confounders or indication bias. Most importantly, the second stage of a two-stage IBBR was not always included.

Bennett et al. compared different types of IBBR during a 2-year follow-up.[27] Reoperative complication rates were 19% after direct-to-implant IBBR and 16% after two-stage IBBR. Although these results were adjusted for confounders and variation between centers, selection bias (confounding by indication) was not limited, and the results were statistically not significant (OR, 1.06; 95% CI, 0.56 to 1.99). Other smaller studies reported comparable proportions of long-term revision surgery between the two IBBR groups (range, 20 to 28%).[28,29] Nevertheless, comparing the current study results to previous studies remains difficult because many different outcome definitions are used, such as reconstructive failure, reoperation, or reoperative complications.[7,18,27,30]

There are two likely explanations for the lower risk of short- and long-term revision surgery in the direct-to-implant IBBR group compared to the two-stage group. First, the reconstruction trajectory of a two-stage IBBR is longer by definition, with two potentially hazardous events instead of one. Second, patient selection may have affected the probability of revision surgery. Direct-to-implant IBBR was more often performed in younger, nonsmoking patients. In addition, fewer infection-control measures were used compared to two-stage IBBR, suggesting that direct-to-implant IBBR was more frequently performed in low-risk patients. However, in the propensity score–matched cohort, in which pseudorandomization was mimicked and the selection bias was limited, comparable results were found.

To further decrease the risk of short-term revision surgery after direct-to-implant IBBR, current findings suggest that one should focus specifically on mastectomy skin flap quality and prevention of deep wound infections. After two-stage IBBR, most short-term revisions were caused by deep wound infections and seroma or hematoma formation. As most of these revision indications were related, different preventive strategies may be useful (eg, prophylactic intravenous tranexamic acid administration and a more aggressive surgical dead space management to prevent hematoma and seroma formation, respectively, and consequently deep wound infections).[31,32] Long-term outcomes of both IBBR techniques could be improved by focusing on patient selection and counseling, especially regarding the risk of asymmetry, breast pain, and dissatisfaction with volume.

Strengths and Limitations

One of the strengths of this study is that real-world data were used from a nationwide

population-based registry, including implants that were followed up over time within different health care institutions. Consequently, the findings reflect daily clinical practice in The Netherlands. RCTs are still the standard for comparative studies. However, RCTs are not always feasible if the outcome has a low event rate. As the next best alternative, selection and indication biases were limited using imputation techniques for missing data and propensity score matching to mimic pseudorandomization. Also, clustering of patients and implants within health care institutions was taken into account. Finally, the DBIR uses definitions similar for all breast implant registries affiliated with the International Collaboration of Breast Registry Activities, thereby improving comparability to future studies and meta-analyses using data from breast implant registries.[33]

There are several limitations. Registration of all inserted and explanted breast implants in the DBIR is mandatory for board-certified plastic surgeons. The registration of inserted implants can be validated using industry sales data, for example. The validation of explanted implants, however, is more difficult, as reliable tools are unavailable. Therefore, revision operations might be underreported without us knowing. Although it is unlikely that revisions were less frequently registered for only one of the IBBR techniques, the presented revision incidences need to be interpreted as minimum incidences. Second, there may be residual confounding, because of missing potential confounders such as mastectomy skin flap quality, breast volume or mastectomy weight, surgeon's experience, and detailed information on adjuvant or neoadjuvant therapy.[3,18,34,35] However, the sensitivity analysis indicated that residual confounding could explain the observed association if an unidentified confounding factor with an odds ratio of at least 5.9 would exist. The majority of the measured confounders had an odds ratio below 2. Therefore, it is unlikely that unidentified confounders would drastically alter the conclusions.

Lastly, postoperative radiotherapy is associated with a higher risk of postoperative complications, and postoperative radiotherapy was registered in approximately 5% of our total study population. This low percentage is in line with the Dutch breast reconstruction guideline, which discourages immediate breast reconstruction if postoperative radiotherapy is indicated, especially with an implant.[14] Therefore, the generalizability of the results may be restricted in countries with different guidelines.

Future Research

In daily practice, health care institutions tend to prefer one technique over the other. Future studies should focus on nationwide variation in the use of both IBBR techniques and the underlying reasons. Insight into variation, patient selection, and outcomes helps to further improve guidelines and the quality of care provided.

CONCLUSIONS

Unplanned revision surgery occurred less often after direct-to-implant IBBR, and a higher proportion of breasts were reconstructed within the planned number of operations compared to two-stage IBBR. These population-based results are important to improve patient counseling and shared decision-making. Besides, they may help to start the discussion about whether a direct-to-implant approach should be considered more often.

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REFERENCES

1. Becherer BE, van Bommel ACM, Hommes JE, et al. *Dutch Breast Implant Registry (DBIR) Annual Report 2018*. Leiden, The Netherlands: Dutch Institute for Clinical Auditing; 2019.
2. Kamali P, Zettervall SL, Wu W, et al. Differences in the reporting of racial and socioeconomic disparities among three large national databases for breast reconstruction. *Plast Reconstr Surg*. 2017;139:795–807.
3. Mylvaganam S, Conroy E, Williamson PR, et al.; iBRA Steering Group. Variation in the provision and practice of implant-based breast reconstruction in the UK: results from the iBRA national practice questionnaire. *Breast* 2017;35:182–190.
4. Ilonzo N, Tsang A, Tsantes S, Estabrook A, Thu Ma AM. Breast reconstruction after mastectomy: a ten-year analysis of trends and immediate postoperative outcomes. *Breast* 2017;32:7–12.
5. Mandelbaum AD, Thompson CK, Attai DJ, et al. National trends in immediate breast reconstruction: an analysis of implant-based versus autologous reconstruction after mastectomy. *Ann Surg Oncol*. 2020;27:4777–4785.

6. Susarla SM, Ganske I, Helliwell L, Morris D, Eriksson E, Chun YS. Comparison of clinical outcomes and patient satisfaction in immediate single-stage versus two-stage implant-based breast reconstruction. *Plast Reconstr Surg.* 2015;135:1e–8e.
7. Davila AA, Mioton LM, Chow G, et al. Immediate two-stage tissue expander breast reconstruction compared with one-stage permanent implant breast reconstruction: a multi-institutional comparison of short-term complications. *J Plast Surg Hand Surg.* 2013;47:344–349.
8. Basta MN, Gerety PA, Serletti JM, Kovach SJ, Fischer JP. A systematic review and head-to-head meta-analysis of outcomes following direct-to-implant versus conventional two-stage implant reconstruction. *Plast Reconstr Surg.* 2015;136:1135–1144.
9. Lee KT, Mun GH. Comparison of one-stage vs two-stage prosthesis-based breast reconstruction: a systematic review and meta-analysis. *Am J Surg.* 2016;212:336–344.
10. Grover R, Padula WV, Van Vliet M, Ridgway EB. Comparing five alternative methods of breast reconstruction surgery: a cost-effectiveness analysis. *Plast Reconstr Surg.* 2013;132:709e–723e.
11. Krishnan NM, Fischer JP, Basta MN, Nahabedian MY. Is single-stage prosthetic reconstruction cost effective? A cost-utility analysis for the use of direct-to-implant breast reconstruction relative to expander-implant reconstruction in postmastectomy patients. *Plast Reconstr Surg.* 2016;138:537–547.
12. Killaars RC, Hommes J, van der Hulst RR, Tielemans HJ, Negenborn VL, Piatkowski A. Does 2-stage implant-based breast reconstruction allow for a larger volume of the definite implant compared with 1-stage reconstruction? *Ann Plast Surg.* 2018;80:481–486.
13. Dikmans RE, Negenborn VL, Bouman MB, et al. Two-stage implant-based breast reconstruction compared with immediate one-stage implant-based breast reconstruction augmented with an acellular dermal matrix: an open-label, phase 4, multicentre, randomised, controlled trial. *Lancet Oncol.* 2017;18:251–258.
14. Mureau MAM; Breast Reconstruction Guideline Working Group. Dutch breast reconstruction guideline. *J Plast Reconstr Aesthet Surg.* 2018;71:290–304.
15. Rakhorst HA, Mureau MAM, Cooter RD, et al. The new opt-out Dutch National Breast Implant Registry: lessons learnt from the road to implementation. *J Plast Reconstr Aesthet Surg.* 2017;70:1354–1360.
16. Hoeijmakers F, Beck N, Wouters M, Prins HA, Steup WH. National quality registries: how to improve the quality of data? *J Thorac Dis.* 2018;10:S3490–S3S99.
17. Piper ML, Roussel LO, Koltz PF, et al. Characterizing infections in prosthetic breast reconstruction: a validity assessment of national health databases. *J Plast Reconstr Aesthet Surg.* 2017;70:1345–1353.
18. Fischer JP, Wes AM, Tuggle CT III, Serletti JM, Wu LC. Risk analysis of early implant loss after immediate breast reconstruction: a review of 14,585 patients. *J Am Coll Surg.* 2013;217:983–990.
19. Suttorp MM, Siegerink B, Jager KJ, Zoccali C, Dekker FW. Graphical presentation of confounding in directed acyclic graphs. *Nephrol Dial Transplant.* 2015;30:1418–1423.
20. van Buuren S. *Flexible Imputation of Missing Data.* 2nd ed. London: Chapman & Hall/CRC; 2018.
21. Sterne JA, White IR, Carlin JB, et al. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *BMJ* 2009;338:b2393.
22. Rubin DB. *Multiple Imputation for Nonresponse in Surveys.* New York: Wiley; 1987.
23. Haneuse S, VanderWeele TJ, Arterburn D. Using the E-value to assess the potential effect of unmeasured confounding in observational studies. *JAMA* 2019;321:602–603.
24. Austin PC. An introduction to propensity score methods for reducing the effects of confounding in observational studies. *Multivariate Behav Res.* 2011;46:399–424.
25. Gfrerer L, Mattos D, Mastroianni M, et al. Assessment of patient factors, surgeons, and surgeon teams in immediate implant-based breast reconstruction outcomes. *Plast Reconstr Surg.* 2015;135:245e–252e.
26. Austin PC. Balance diagnostics for comparing the distribution of baseline covariates between treatment groups in propensity-score matched samples. *Stat Med.* 2009;28:3083–3107.
27. Bennett KG, Qi J, Kim HM, Hamill JB, Pusic AL, Wilkins EG. Comparison of 2-year complication rates among common techniques for postmastectomy breast reconstruction. *JAMA Surg.* 2018;153:901–908.
28. Roostaeian J, Sanchez I, Vardanian A, et al. Comparison of immediate implant placement versus the staged tissue expander technique in breast reconstruction. *Plast Reconstr Surg.* 2012;129:909e–918e.
29. Clarke-Pearson EM, Lin AM, Hertl C, Austen WG, Colwell AS. Revisions in implant-based breast reconstruction: how does direct-to-implant measure up? *Plast Reconstr Surg.* 2016;137:1690–1699.
30. Hvilsom GB, Friis S, Frederiksen K, et al. The clinical course of immediate breast implant reconstruction after breast cancer. *Acta Oncol.* 2011;50:1045–1052.
31. Heyns M, Knight P, Steve AK, Yeung JK. A single preoperative dose of tranexamic acid reduces perioperative blood loss: a meta-analysis. *Ann Surg.* 2020;273:75–81.
32. Jordan SW, Khavanin N, Kim JY. Seroma in prosthetic breast reconstruction. *Plast Reconstr Surg.* 2016;137:1104–1116.
33. Spronk PE, Begum H, Vishwanath S, et al. Toward international harmonization of breast implant registries: ICOBRA global common dataset. *Plast Reconstr Surg.* 2020;146:255–267.
34. McCarthy CM, Mehrara BJ, Riedel E, et al. Predicting complications following expander/implant breast reconstruction: an outcomes analysis based on preoperative clinical risk. *Plast Reconstr Surg.* 2008;121:1886–1892.
35. Fischer JP, Wes AM, Tuggle CT, Serletti JM, Wu LC. Risk analysis and stratification of surgical morbidity after immediate breast reconstruction. *J Am Coll Surg.* 2013;217:780–787.