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ORIGINAL ARTICLE BREAST SURGERY

50 Shades of Red: The Predictive Value of Closed Suction Drains for the Detection of Postoperative Bleeding in Breast Surgery

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Abstract
Background While closed suction drains (CSDs) are still frequently employed in clinical practice, the supporting evidence is limited with some studies demonstrating a failure of routine CSD use in preventing hematoma or seroma. Nonetheless, CSD quantity and quality fluid assessment is still appreciated by clinicians to detect postoperative bleeding. This study investigates the value of routine CSD use, in breast surgery, to predict postoperative bleeding.
Methods A retrospective, intra-individual analysis, of CSD fluid volumes between the hematoma side and the unaffected contralateral breast, was undertaken in patients ($n = 20$) with unilateral postoperative bleeding following bilateral breast surgery (2003–2018). Statistical analysis was undertaken to establish a minimum cutoff fluid volume that might assist in the detection of postoperative bleeding. To determine the usefulness of quality assessment of CSD fluid output by visual inspection, surgeons ($n = 56$) prospectively matched six eligible hemoglobin concentrations corresponding to pre-filled CSDs.
Results Statistical analysis did not yield a clinically reliable cutoff fluid volume indicating postoperative bleeding. All six eligible hemoglobin concentrations were completely successfully matched to pre-filled CSDs by 30.4% (17/56) of surgeons.
Conclusions This study questions the significance of routine CSD use to assist in the decision-making process to return to the theater and address postoperative bleeding. Quantity as well as quality analysis of CSD fluid output failed the reliability and diagnostic validity tests. Hemoglobin measurements in drain fluid specimens via blood gas analysis might contribute to the detection of postoperative bleeding.
Level of Evidence IV This journal requires that authors assign a level of evidence to each article. For a full description of these Evidence-Based Medicine ratings, please refer to the Table of Contents or the online Instructions to Authors www.springer.com/00266.

Keywords Closed suction drains (CSDs) · Breast surgery · Prediction of postoperative bleeding · Diagnostic validity

Introduction

Clinicians use closed suction drains (CSDs) for a variety of reasons. These include monitoring and prevention of fluid accumulation or reduction of dead space within a wound cavity. Despite their implementation in clinical practice, the relevance of routine CSD use has been an ongoing debate for several decades [1–5]. Furthermore, their usefulness in preventing complications has also been questioned, with some studies highlighting a failure of routine CSD use in preventing seroma or hematoma formation in plastic surgery procedures [6–15]. In addition to thorough clinical examination, with detection of local and systemic features of ongoing bleeding, CSD output quantity and quality assessment is still used as part of the key criteria in

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determining the presence of postoperative bleeding by clinicians including doctors and nurses [2, 16–18].

The overall aim of this study was to examine the value of CSD use, in the prediction of postoperative bleeding, in patients undergoing routine breast surgery procedures. The focus of the study was to address three primary objectives. The first objective was to establish whether intra-patient differences, in CSD output volume, could be demonstrated between breast sides affected by postoperative bleeding and contralateral sides that were unaffected. The second objective was to establish a cutoff value for minimum CSD output volume that might indicate the presence of ongoing bleeding in breast surgery. The final objective was to investigate whether surgeons are able to accurately detect drain fluid that is suspicious of postoperative bleeding by visual quality assessment.

Materials and Methods

Institutional research ethics committee approval (Ref. 18-955-104) was obtained prior to the initiation of this study. The authors adhered to the Standards for Reporting Diagnostic Accuracy Studies (STARD) guidelines (Fig. 1). A retrospective analysis of 2175 patients who underwent reduction mammoplasty, augmentation mammoplasty and gynecomastia treatment with subcutaneous mastectomy was performed between January 2003 and January 2018 (Fig. 1). The cohort was screened for patients who suffered from ongoing bleeding, necessitating revision surgery within 24 h postoperatively. To allow an intra-patient comparison of the quantity of CSD fluid output between breast sides affected by postoperative bleeding and unaffected contralateral breasts, study inclusion was limited to bilateral breast surgeries. The exclusion criteria were patients who had unilateral breast surgery, patients undergoing adjunctive surgeries such as liposuction and patients without drains. One-out-of-two lead surgeons with equivalent experience in breast surgery performed the procedures. All patients were treated in an inpatient setting under general anesthesia corresponding to national common practice.

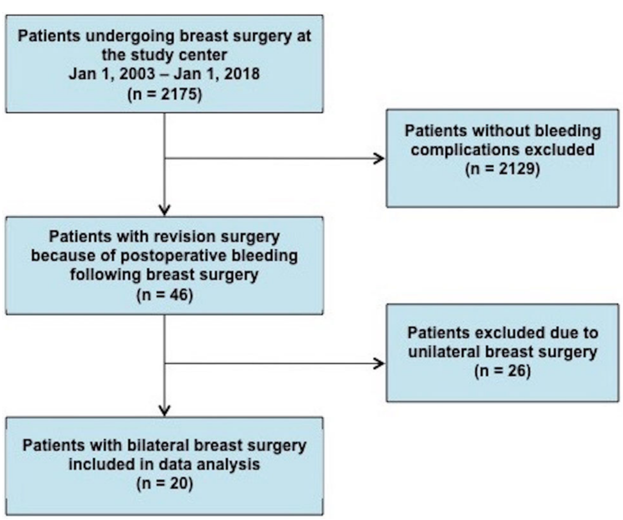

Fig. 1 Patient selection flowchart according to the Standards for Reporting Diagnostic Accuracy Studies (STARD) guidelines

All statistical analyses were performed using IBM SPSS for Mac Version 24.0.0.0 (IBM Corp., Armonk, N.Y.).

Intra-individual Comparison of CSD Output Volumes

Patient notes were retrospectively analyzed for bilateral breast surgeries, demographics, laboratory findings, operation dates, postoperative bleeding events and associated CSD output volumes (Table 1). Drain outputs were consistently recorded from CSDs connected via a 12 Charriere diameter drain tube, with one CSD placed per breast. This allowed an intra-individual comparison of drain fluid volumes between the side affected by ongoing bleeding and the unaffected contralateral breast. Drain output volumes were analyzed using a nonparametric Wilcoxon signed-rank test to detect potential differences between drain fluid volumes, prior to revision surgery, between the affected and unaffected breast sides. The null hypothesis was that no significant difference would be demonstrated.

Diagnostic Power Analysis of CSD Output and Related CutOff Volume for Predicting OnGoing Bleeding

The receiver operating characteristic curve (ROC) analysis is a valuable tool for determining the diagnostic power of a test (Fig. 2) [19, 20]. To measure the accuracy of a diagnostic test, the area under the ROC curve (AUC) is assessed. An AUC of 1 indicates a perfect test, whereas an AUC of 0.5 represents no better accuracy than chance (Table 2) [19, 20]. In this study, the AUC was calculated to determine the diagnostic value of drain output volume as an indicator for ongoing bleeding.

The Youden index (J) is frequently utilized in conjunction with a ROC curve analysis to illustrate the performance of a diagnostic test for specific cutoff values [19]. J may range from 0 to + 1, with a value of + 1 representing an optimal test (Table 3). Sensitivity, specificity, and positive and negative predictive values were calculated in relation to specific cutoff values to determine a precise CSD output volume that might be predictive of ongoing bleeding (Table 3).

Table 1 Study population characteristics (n = 20)

Mean age (years)	M = 39.2 (SD = 14.8)
Female	n = 14
Male	n = 6
Breast reduction	n = 6
Augmentation mammoplasty	n = 8
Subcutaneous mastectomy	n = 6
Preoperative Hb (g/dl)	M = 13.7 (SD = 1.8)
Preoperative Ht (%)	M = 43.2 (SD = 5.7)
Postoperative Hb (g/dl)	M = 11.0 (SD = 1.8)
Preoperative Ht (%)	M = 34.7 (SD = 5.7)
Drain output hematoma side (ml)	M = 99.7 (SD = 104.2); Mdn = 60.0 (IQR = 85.0)
Drain output non-hematoma side (ml)	M = 42.5 (SD = 42.6); Mdn = 32.5 (IQR = 55.0)

Mean (M) values are presented with standard deviation (SD). Median (Mdn) values are presented with interquartile range (IQR)

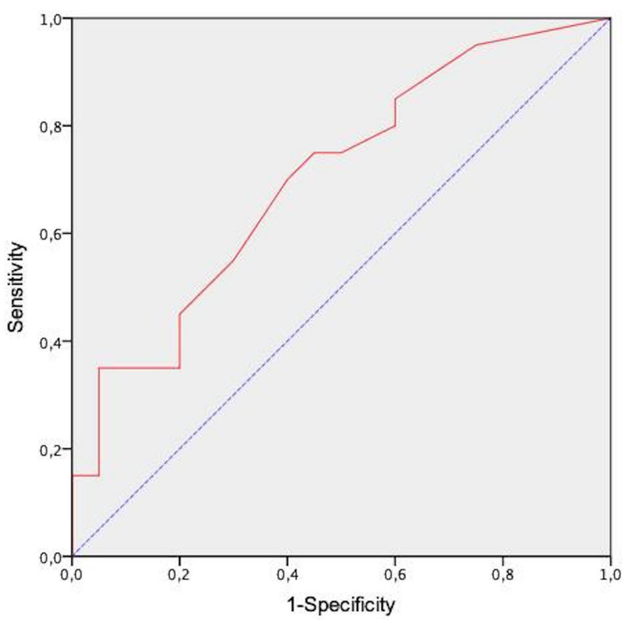

Fig. 2 Receiver operating characteristic curve (ROC) (blue line) of drain output for the prediction of postoperative bleeding following breast surgery. *Y*-axis displays sensitivity (true positive rate), and *X*-axis presents 1-specificity (false positive rate). The area under the curve (AUC) determines the diagnostic value of drain output. A diagnostic test able to perfectly identify patients with or without bleeding/hematoma would have an AUC of 1. In contrast, the curve of a worthless test would fall on the diagonal (black line) (AUC of 0.5). The results of this test resulted in an AUC of 0.703 (95% CI 0.541–0.864)

Table 2 AUC values and related diagnostic accuracies [19, 20]

AUC	Diagnostic accuracy
> 0.9	Excellent
> 0.8	Very good
> 0.7	Good
> 0.6	Sufficient
> 0.5	Bad
≤ 0.5	Test not useful

Prospective CSD Fluid Output Quality Assessment

To explore the extent to which CSD fluid quality visual analysis solely, independent of the quantity of drain output, could assist in the diagnosis process of ongoing bleeding, surgeons were asked to inspect pre-filled CSD container contents under standardized, double-blind conditions. For this prospective survey, six empty CSD bottles were filled to a total volume of 200 mls each. The content of each CSD bottle was a mixture of clear, serous drain fluid taken from one inpatient to gain adequate drain fluid viscosity, augmented with ABO-compatible stored blood that had been stepped down from patient usage stores within the preceding 24 h, giving color to the serous fluid. Stored blood was gradually added to the serous drain fluid in the containers to adjust specific hemoglobin (Hb) and hematocrit (Ht) concentrations under continuous Hb/Ht measurements using a blood gas analyzer. The Hb (Ht) concentrations ranged between 0.1 g/dl (Ht 0.4%) and 9.0 g/dl (Ht 28.3%) (Fig. 3). The upper value of 9.0 g/dl (Ht 28.3%) was chosen after a pilot trial revealed that Hb concentrations exceeding 9.0 g/dl (Ht 28.3%) in terms of color were visually indistinguishable from one another.

Plastic surgeons were asked to match the six eligible, pre-defined Hb concentrations, with the prepared unlabeled CSD bottles, and a comparison was made between trainees (< 5 years professional experience) and qualified residents/consultants (> 5 years professional experience) (Fig. 4). The surgeons received a list stating the six eligible Hb concentrations. The investigator showed the CSD bottles to the participants one at a time in random order asking the surgeon to select the according Hb value from the list. Further to the Hb/CSD container matching, all surgeons

Table 3 Sensitivity and specificity for various cutoff CSD output volumes with corresponding *J* values

Cutoff value (ml)	Sensitivity (95% CI)	Specificity (95% CI)	PPV	NPV	*J*
10.0	0.95	0.25	0.56	0.83	0.20
22.5	0.85	0.40	0.59	0.73	0.25
27.5	0.80	0.40	0.57	0.67	0.20
32.5	0.75	0.50	0.60	0.67	0.25
37.5	0.75	0.55	0.63	0.69	0.30
45.0	0.70	0.60	0.64	0.67	0.30
55.0	0.55	0.70	0.65	0.61	0.25
65.0	0.45	0.80	0.69	0.59	0.25
72.5	0.35	0.80	0.64	0.55	0.15

A cutoff volume of 45.0 mls presented the highest *J* value with the best compromise between sensitivity and specificity

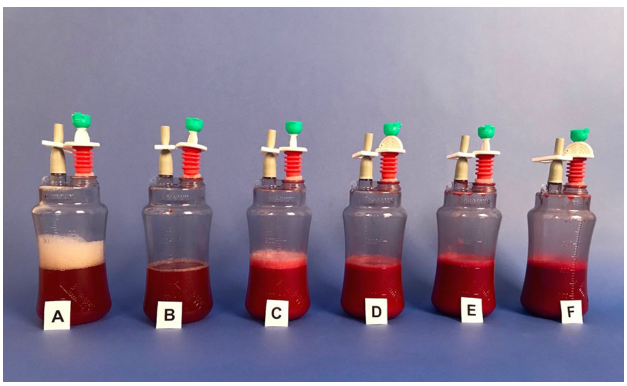

Fig. 3 Estimation of drain fluid composition. CSD bottles (A–F) were prepared using clear drain output fluid collected from one patient and supplemented with ABO-compatible blood, with Hb values in the ascending order from $A = 0.1$ g/dl (Ht = 0.4%), $B = 0.3$ g/dl (Ht = 1.3%), $C = 1.0$ g/dl (Ht = 3.8%), $D = 3.0$ g/dl (Ht = 10.2%), $E = 6.0$ g/dl (Ht = 18.6%) to $F = 9.0$ g/dl (Ht = 28.3%). Participants were asked to match the bottles with their corresponding Hb concentrations under standardized conditions by visual inspection. Surgeons correctly estimated the Hb level in all 6 CSD bottles in 30.4% (17/56) of cases. Lower Hb levels (≤ 1.0 g/dl; Ht ≤ 3.8%) were estimated correctly more frequently (38.1%; 64/168) than higher Hb levels (≥ 3.0 g/dl; Ht ≥ 10.2%) (25.6%; 43/168)

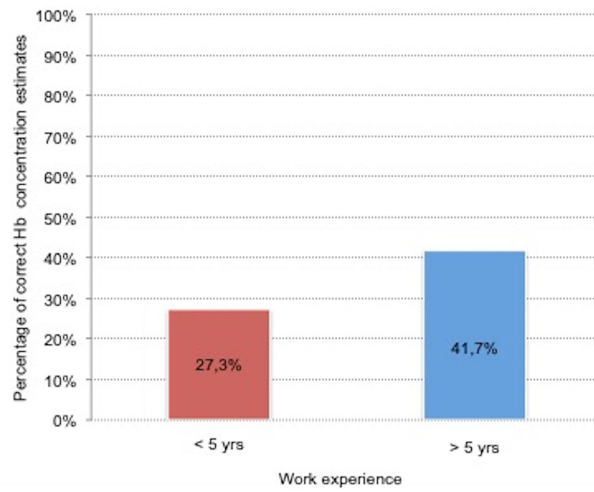

Fig. 4 Drain fluid composition. The proportion of correct estimates between surgeons with lower work experience (< 5 years) and more advanced physicians (> 5 years work experience) was not statistically significant ($p = 0.48$)

were asked to decide whether the quality of drain fluid in each CSD container would be suspicious of ongoing postoperative bleeding. A two-sided Fisher's exact test was undertaken to verify whether professional experience (< 5 years vs. > 5 years) had any effect on the correct matching of CSD bottles with eligible Hb values (Fig. 4).

To obtain an indicator of the Hb (Ht) concentration within CSD fluid output in vivo, eight patients undergoing bilateral breast surgery were randomly selected within 24 h postoperatively and their CSD fluid output was tested for Hb (Ht) concentration via blood gas analysis. Indeed, two of the prospectively enrolled patients required surgical washout for ongoing bleeding following breast surgery and Hb (Ht) could be obtained in the drain fluid of the affected breast side.

Results

Intra-individual Comparison of CSD Output Volumes

Among the total number of 2175 patients, 2.11% (46/2175) suffered an event of postoperative bleeding following uni- or bilateral breast surgery requiring revision within 24 h (Fig. 1). Twenty-six subjects (n = 26) were excluded for unilateral breast surgery (Fig. 1). Twenty (n = 20) subjects could be detected who met the pre-defined inclusion criteria (Fig. 1).

One hundred percent (20/20) of patients underwent elective surgical procedures and had an ASA I/II status

(Table 1). All patients had normal INR and PTT parameters, with procedures performed in a standard manner using mono- and bipolar diathermy hemostasis.

Non-normal data distribution was confirmed by Shapiro–Wilk test for CSD output volumes in bleeding affected ($p = 0.008$) and unaffected breasts ($p < 0.001$). Furthermore, descriptive statistics revealed positively skewed data distribution for postoperative bleeding events (1.821) as well as for unaffected (i.e., non-bleeding) breasts (1.505). Accordingly, results are represented as median (Mdn) values with corresponding interquartile ranges (IQR).

Wilcoxon signed-rank testing resulted in a significant difference in CSD output volumes between the breast side affected by ongoing postoperative bleeding (Mdn = 60.0 mls, IQR = 85.0 mls; range (R) = 0–400 mls) and the unaffected side (Mdn = 32.5 mls, IQR = 55.0 mls; R = 0–170 mls, $Z = -2.962$, $p < 0.003$). In 30% (6/20) of patients, CSD output volumes were same or less on the clinically affected side versus the unaffected side.

Diagnostic Power Analysis of CSD Output and Related CutOff Volume for Predicting OnGoing Bleeding

Figure 2 illustrates a ROC curve, which is a plot of the true positive rate against (sensitivity) the false positive rate (1-specificity) for a range of cutoff CSD output volumes. ROC curve diagnostic validity testing yielded an AUC ranging from 0.5 to 0.9 (95% CI) (Table 2) [21]. The wide span of diagnostic accuracy makes drain fluid quantity assessment unreliable for clinical testing (Table 2).

Table 3 details the sensitivity and specificity, positive (PPV) and negative predictive values (NPV), for specific CSD output cutoff volumes together with corresponding J values. Regarding the accuracy of the prediction of ongoing bleeding using CSD output quantity, ROC and corresponding J values indicated that the most appropriate minimum cutoff value was a CSD drainage output of 45.0 mls/24 h ($J = 0.30$, sensitivity = 0.7, specificity = 0.6). This cutoff volume predicted a 64% chance of associated postoperative bleeding (PPV 0.64).

Prospective CSD Fluid Output Quality Assessment

Fifty-six surgeons ($n = 56$) prospectively visually evaluated six CSD containers, comprising different Hb (Ht) concentrations and a consistent volume of 200 mls each. Complete success, in matching all six eligible, pre-defined Hb (Ht) values, was achieved by 30.4% (17/56) of surgeons (Fig. 3). Trainees correctly matched all six Hb (Ht) concentrations in 27.3% (12/44) of cases, whereas residents and consultants provided correct estimates in 41.7% (5/12) of cases (Fig. 4). Two-sided Fisher's exact testing, however, did not support a significant difference between these two groups ($p = 0.48$).

Lower ($\leq$ 1.0 g/dl, Ht $\leq$ 3.8%) Hb (Ht) levels were correctly matched with the related CSD containers more frequently (38.1%; 64/168) than higher ($\geq$ 3.0 g/dl, Ht $\geq$ 10.2%) Hb (Ht) levels (25.6%; 43/168). Interestingly, 25.0% (14/56) of surgeons suggested possible postoperative bleeding when interpreting the quality of drain output associated with an Hb value of 1.0 g/dl (Ht 3.8%) only. A suspected diagnosis of hematoma requiring revision surgery increased with higher CSD Hb levels. No (0/56) surgeon suspected possible postoperative bleeding following drain output quality evaluation of the bottles containing an Hb of 0.1 g/dl (Ht 0.4%), 25.0% of participants (14/56) suspected bleeding in the drain container with an Hb of 1.0 g/dl (Ht 3.8%) in the CSD output, and 100% (56/56) of surgeons predicted bleeding when inspecting the bottle corresponding to an Hb value of 9.0 g/dl (Ht 28.3%) (Table 4).

Of the eight patients prospectively enrolled to obtain an indicator of in vivo Hb concentrations within CSD fluid outputs, breast hematoma requiring surgical washout was indeed noted in two patients within 24 h postoperatively; drain fluid Hb (Ht) analysis yielded a mean Hb of 12.4 g/dl (M(Hb) = 12.4 g/dl ± SD = 0.4 g/dl; R = 12.0–12.8 g/dl; M(Ht) = 39.1%). The mean Hb concentration in CSD fluid in patients ($n = 6$) who did not suffer from ongoing bleeding was 4.1 g/dl (M(Hb) = 4.1 g/dl ± SD = 1.3 g/dl; R = 2.1–5.8 g/dl; M(Ht) = 12.4%) 24 h postoperatively.

Discussion

Although postoperative hematoma rates may be as low as 1% in breast reduction mammoplasty and 1–6% in augmentation mammoplasty, undetected postoperative bleeding is among the greatest fears of surgeons due to potentially life-threatening consequences and inferior cosmetic outcome [7, 18, 22–24]. Despite the primary rationale for using drains to prevent fluid collection within the wound cavity, various studies have failed to prove the benefit of CSDs in preventing hematoma formation in breast surgery [5–8, 25, 26]. Even so, along with wound inspection, palpation and swelling, high-volume drain output is assumed as an indicator of ongoing bleeding prior to unstable vital parameters and many surgeons appreciate CSDs as a monitoring tool to evaluate the quality and quantity of fluid in the CSD reservoir [2, 16, 17, 23]. In fact, 79% of surgeons stated that they routinely used drains in a survey of 140 consultant plastic surgeons in the UK and Ireland [27]. Likewise, our institution used to rely on drains as a screening method for the detection of

Table 4 CSD samples, Hb/Ht concentrations and corresponding comments by study participants

CSD sample	Hb level (g/dl)	Ht level (%)	Suspected diagnosis of active bleeding (%)
A	0.1	0.4	0
B	0.3	1.3	11.1
C	1.0	3.8	25.0
D	3.0	10.2	33.3
E	6.0	18.6	83.3
F	9.0	28.3	100.0

postoperative bleeding in breast surgery. With regard to closed wounds, drain volume is an objective criterion among other more subjective clinical symptoms such as pain or swelling used for the early diagnosis of postoperative bleeding. The intra-individual comparison in this study found a statistically significant difference between drain output volumes on the breast side affected by postoperative bleeding (Mdn = 60.0 mls, IQR = 85.0 mls) and the unaffected contralateral breast (Mdn = 32.5 mls, IQR = 55.0 mls, $p < 0.0003$). When CSD output was analyzed to determine a minimum cutoff volume for the prediction of ongoing bleeding, a value of 45.0 mls/24 h was obtained. Nevertheless, according to the statistical analyses via ROC curve and Youden index (*J* value) of this study, the diagnostic validity of using drain volume output as a screening tool for hematoma formation in breast surgery is questionable (Fig. 2, Tables 2, 3). The ROC curve diagnostic validity testing yielded a wide AUC range from 0.5–0.9 (95% CI) (Table 2) [21]. This critical bandwidth of diagnostic accuracy makes drain fluid quantity assessment unreliable for clinical testing (Fig. 2, Table 2). According to the obtained *J* value, 45 mls/24 h is the best compromise between sensitivity and specificity to detect ongoing bleeding and theoretically this volume limit would be the best threshold level used for the purpose of CSD volume screening to rule out postoperative bleeding (Table 3). However, from a clinician's perspective 45 mls/24 h is a problematic threshold, because many patients will have this drain volume output without any event of ongoing bleeding. Statistically, this particular volume corresponds with the highest *J* value ($J = 0.30$), which in turn represents the best compromise between specificity (0.6) and sensitivity (0.7) (Fig. 2, Table 3). The higher the sensitivity rate, the more bleeders (true positives) are detected. High specificity means that true negatives or non-bleeders are easily identified. Especially, as a consequence of the low specificity of the performed test ("CSD output quantity") in this trial of 0.6, many non-bleeders (false positives) are wrongly detected by the test when choosing a drain output cutoff value of 45 mls/24 h. In contrast, choosing higher, more realistic cutoff volume levels from a clinical point of view, results in a further decline of sensitivity and potential blood loss might not be diagnosed although clinically relevant (Table 3).

Despite that, it needs to be emphasized that the *J* value ($J = 0.30$) is still very low, which underlines the unreliable nature of CSD volume as a marker for the detection of ongoing bleeding. Hence, decision-making based on the acquired cutoff value cannot be recommended regardless of its theoretical statistical justification.

One explanation for the inadequate capability of drains as a diagnostic parameter for the detection of postoperative bleeding is blood coagulation that might cause early in-drain clotting, which in turn distorts volumes in the CSD reservoir independent from ongoing bleeding within the wound cavity. Remarkably, within this study cohort 6 out of 20 patients (30.0%) with revision surgery presented a fluid volume in the drain container of the affected breast which was equal or even less compared to drain output of the unaffected contralateral breast (Table 1). In contrast, ongoing bleeding with hematoma formation was evident during revision surgery in 100% (20/20) of the patients. According to the insights of this study, in-drain clotting is assumed as the leading cause for this observation, in which blood coagulation prevented fluid collection through the drain tube, which is line with other investigations in this field that questioned CSDs to reliably prevent hematoma formation [6, 8, 12, 13].

Consequently, when used as a single independent diagnostic criterion in clinical practice, CSD volume may be unreliable to indicate revision surgery for the cause of postoperative bleeding.

Given this, our study strove to identify the significance of drain fluid output quality assessment in the diagnostic process of postoperative bleeding.

As postoperative mortality and morbidity are known to increase dramatically below serum Hb levels of 7 g/dl, some surgeons consider visual inspection of drain output as another monitoring tool with regard to early detection of postoperative bleeding [16, 28]. In fact, the World Health Organization introduced a hemoglobin color scale for the purpose of anemia screening in developing countries; this involves blood absorption onto a test strip, with a range of potential color shades corresponding to pre-defined Hb concentrations [29]. Only 30.4% (17/56) of surgeons, enrolled in the prospective component of this study, correctly matched the eligible Hb concentrations with the 6 pre-filled CSD bottles by visual inspection (Fig. 3). While the authors recognize that a 100% success rate being indicative of a successful test is a stringent criterion, accuracy of CSD fluid output assessment would be improved with the assistance of formal sample testing [29]. Laboratory Hb (Ht) evaluation of drain fluid samples would be particularly useful when interpreting Hb (Ht) concentrations above 3 g/dl (Ht 10.2%), when it becomes even more difficult to distinguish color differences in CSD output quality purely by inspection (Fig. 3). Many institutions, including our own, collect blood specimens from suspicious CSDs and evaluate the Hb (Ht) concentration using the assistance of blood gas analyzers. Even though this method will provide accurate results of drain fluid quality composition, it is still not clear which Hb (Ht) level could be indicative of postoperative bleeding indicating revision surgery; this is particularly true when considered in relation to the volume of CSD fluid output. From the samples of CSD fluid output prospectively obtained and tested in non-bleeding breasts in this study, a mean Hb of 4.1 g/dl (Ht 12.4%) was determined as being normal 24 h postoperatively ($n = 6$). Formal sample testing in the drain fluid of affected breasts requiring surgical revision Hb was 12.4 g/dl (M(Hb) = 12.4 g/dl ± SD = 0.4 g/dl; R = 12.0–12.8 g/dl; M(Ht) = 39.1%; $n = 2$). Nonetheless, clinical examination of the surgical site and the patient status, including systemic observations and blood markers such as serum Hb concentration, would be more conclusive in assisting the decision for, or against revision surgery.

Although the data of this study shed new light on the diagnostic value of CSDs, the significance is certainly limited by various factors.

One might argue that wound extent differs depending on patient specific variables, such as breast size or body mass index (BMI) as well as surgical variables including operative technique and resection weights, potentially influencing drain output. With 46 out of 2175 (2.11%) breast surgery patients suffering from postoperative bleeding during the 15-year observation period, bleeding complications were rare in our patient cohort. This finding corresponds to hematoma rates reported in the literature of 3.7% following breast reduction mammoplasty and surgical revision rates due to postoperative bleeding of 2.6% after subcutaneous mastectomy for gynecomastia [23, 30]. The rather small size of the study cohort ($n = 20$) is a consequence from a low bleeding complication rate together with the narrow inclusion criteria. On the other hand, narrowing the inclusion criteria to bilateral breast patients only offered the unique opportunity of an intra-individual comparison to precisely evaluate the diagnostic value of CSD volume. Thus, further consideration of patient specific and surgical variables with additional breakdown of data was consistently abandoned. Clearly, the fact that postoperative bleeding was rare, in breast surgery procedures included in this study, resulted in a modest sample size of patients being retrospectively and prospectively analyzed. However, there is a lack of published data that focus on CSD quality interpretation as being indicative of ongoing bleeding, and further studies should be commissioned to look into this.

Another potential source of bias was that surgeons were asked to estimate CSD fluid bottles by matching six pre-known Hb concentrations, although participating surgeons and study supervisors were blind as to the exact values of each bottle. While we recognize that the pre-knowledge of the eligible Hb concentrations certainly does not reflect the clinical setting, even with this advantage it was not possible for clinicians to reliably estimate the quality of CSD content by visual inspection alone.

Conclusion

Early detection of postoperative bleeding is imperative in circumventing potentially life-threatening complications. The diagnosis of ongoing bleeding and hematoma formation involves thorough patient assessment as well as evaluation of drain output quantity and quality. Opposed to its wide clinical application, there is limited evidence supporting CSD use as an indicator of postoperative bleeding. This study found that diagnostic validity of drain output quantity and quality assessment is unreliable as a single criterion for the detection of ongoing bleeding in breast surgery. Hb/Ht measurements in drain fluid specimens via blood gas analysis might contribute to the detection of postoperative bleeding.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval Institutional research ethics committee approval (Ref. 18-955-104) was obtained prior to the initiation of this study.

Informed Consent Informed patient consent was obtained.

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