Drainology: Leveraging Research in Chest Drain Management
to Enhance Recovery After Cardiothoracic Surgery

Kevin W. Lobdell MD,1* Louis P Perrault MD PhD,2 Rachel H Drgastin BS;3 Alessandro Brunelli MD,4 Robert J Cerfolio MD MBA,5 Daniel T Engelman MD,6 on behalf of the ERAS Cardiac Society Working Group†

1Sanger Heart & Vascular Institute, Charlotte, North Carolina, USA
2Montréal Heart Institute, Université de Montréal, Montréal, Quebec, Canada
3Oregon Health and Science University School of Medicine, Portland, Oregon
4Leeds Teaching Hospitals, Leeds, UK
5NYU Langone Health, New York, New York, USA
6Heart & Vascular Program, Baystate Health, University of Massachusetts Chan Medical, School-Baystate, Springfield, MA, USA

Word count (max 2500 body text): 3361
Figures: 2
Tables: 1
References: 57

†Other members of the ERAS Cardiac Society working group are: Michael C Grant MD; Rawn Salenger MD; Shannon Crotwell RN, CCRN; and Busra Cangut MD

Competing interest and financial disclosures:
K.W.L. reports consulting relationships with Abiomed, Alexion, Medela, Medtronic, and Renibus Therapeutics.
L.P.P. reports consulting relationships with Clearflow, Circulatech, Abbvie and Marizyme.

R.H.D reports no financial disclosures

A.B. reports consulting relationships with Astra Zeneca, BMS, MSD, Ethicon, and Roche.

R.J.C. reports no financial disclosures.

D.T.E. reports that he is on the Device Safety Monitoring Board for Edwards Lifesciences Medical and the advisory boards of Astellas Pharma, Alexion, Terumo, Medela, Arthrex, and Renibus Therapeutics.

M.C.G. reports no financial disclosures.

R.S. reports relationships with Terumo, Encare, La Jolla, Atricure, Zimmer Biomet, and JACE Medical.

S.C. reports no financial disclosures.

B.C. reports no financial disclosures.

Funding: Funds for the assistance of a professional medical writer were provided by Medela. The medical writer was selected by the authors, who maintained full freedom of investigation and control over manuscript content.

*Corresponding Author: Kevin W. Lobdell, Sanger Heart & Vascular Institute, 1237 Harding Place Innovation Center-5th Floor Charlotte NC 28204; Phone 704.355.1585;

k.lobdell@erascardiac.org,
ABBREVIATIONS

CABG  coronary artery bypass grafting
CPPF  continuous posterior pericardial flushing
ICU   intensive care unit
LOS   length of stay
POAF  postoperative atrial fibrillation
RCT   randomized controlled trial
SOC   standard of care

Central Message: Wide variation in the use of chest drains after cardiothoracic surgery can compromise consistency of care and outcomes. The new science of drainology represents an opportunity for quality improvement.

Perspective Statement: Current practices for chest drain management are typically based on clinical tradition due to a lack of quality evidence. An iterative process of reviewing new research, building standardized best practices around the findings, identifying knowledge gaps, and conducting new studies designed to bridge them is needed to improve postoperative care and patient outcomes after cardiothoracic surgery.

Abbreviated Legend for Central Picture: Quality improvement in chest tube management through evidence-based standardization.
Introduction

Chest drains are customary in patients recovering after cardiothoracic surgery though practices vary widely between clinicians, specific procedures, and institutions. In the absence of evidence-based standards, variation may be attributed to experience and may threaten optimal clinical outcomes. Additional research will develop insight and optimize practices in chest drain management, thereby improving perioperative care (Figure 1).

The concept of “drainology” was forwarded as the science of chest drain management and the inaugural symposium titled, “Drainology: Managing Chest Drains in the Postoperative Patient” ensued at the 102nd annual meeting of the American Association of Thoracic Surgeons (AATS).

At that meeting, experts in both cardiac and thoracic surgery gathered to discuss key topics in chest drain management with the objective of stimulating discussion, inspiration, collaboration, and generation of new evidence-based best practice. The early and enthusiastic response to drainology has stimulated further work;¹ this updated review incorporates the key discussions from the original AATS symposium, subsequent presentations and publications of pertinent research, and a review of recent literature.

Methods

A search of PubMed and Scopus was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines,² in order to identify relevant literature published between 2009 and 2024. Primary search terms included: chest tube, thoracostomy, chest drainage, chest drain, chest tube clogging, retained blood, anti-clogging, retained blood syndrome, active tube clearance, digital drainage. To capture any product-specific
articles, the following search terms were included: PleuraFlow, Thoraguard, Thopaz, DrenTech, Digivent, Atmos, co-axial drain, Blake Drain, channel drain. Secondary search terms included: thoracic surgeon, cardiac surgeon, heart surgeon, thoracic surgeon, thoracic surgery, cardiac surgery, heart surgery, cardiac, thoracic.

Articles were selected for screening if they included one or more of the primary search terms and one or more of the secondary search terms in the title or abstract. Two reviewers (RD and LP) screened the abstracts and full texts. Articles were excluded if they were not related to postoperative chest drainage, included only a pediatric population, included veterinary medicine, and/or included the following terms: trauma, emergency department, prehospital, pulmonologist, needle, percutaneous, paramedic, pain, lysis, fibrinolysis, pleural lysis, pleurodesis, talc, spontaneous, chylothorax. The resulting articles were further divided according to cardiac or thoracic focus.

**Results**

The initial search yielded 3,069 articles, of which 191 were duplicates and 2,878 were selected for screening following the PRISMA inclusion criteria. (Figure 2) A total of 2,418 publications were found to be irrelevant and 460 full-text articles were further assessed for eligibility. An additional 149 were excluded for having the wrong intervention, wrong indication, trauma/emergency setting, pediatric population, or manuscript retracted, and therefore 311 articles were included in the review (Appendix A). Of those, 57/311 (18.3%) were related to drainage after cardiac surgery and 254/311 (81.7%) were related to drainage after thoracic surgery. Of the 57 articles related to cardiac surgery, 21/57 (37%) were focused on active tube
clearance and 2/57 (3.5%) were focused on digital drainage. Of the 254 articles related to thoracic surgery, 36/254 (14%) were focused on digital drainage and 1/254 (0.4%) was focused on active tube clearance.

**Chest drains: The guidelines so far**

Cardiac and thoracic surgeons commonly experience distinct postoperative challenges. For example, postoperative hemorrhage and retained blood are risks after cardiac surgery and air leak is rare, while air leak is a more common problem after pulmonary resection and hemorrhage is encountered less frequently. Nevertheless, both disciplines share a need for standardization and may be able to benefit through collaboration and sharing of evidence and insights. Evidence-based guidelines for perioperative care after cardiac and pulmonary surgery, the former published by the Enhanced Recovery After Surgery (ERAS®) Cardiac Society and the latter by the ERAS® Society and the European Society of Thoracic Surgeons (ESTS), each contains recommendations specific to chest tube management (Table 1).

**Chest tube patency and prevention of retained blood**

Postoperative hemorrhage requiring reoperation is a major complication, but even in the absence of overt hemorrhage, smaller amounts of retained mediastinal blood are common after cardiac surgery. This blood is associated with pro-inflammatory processes including hemolysis, oxidation of cell-free hemoglobin, recruitment of immune cells, and generation of reactive oxygen species that affect the myocardium. Hence, reliably evacuating shed blood from the thorax and mitigating risks of hemorrhage, hemothorax, tamponade, pericardial and/or pleural effusion, postoperative atrial fibrillation (POAF), organ dysfunction, and infections are central to
successful recovery. These complications are also associated with increased ventilation time, ICU and hospital LOS, 30-day readmissions, mortality, and associated healthcare costs.\textsuperscript{8-12}

While as many as 2.6\% of cardiac surgery patients undergo reoperation for hemorrhage after cardiac surgery, it has been estimated that as many as 15 to 20\% of cardiac surgery patients may require intervention for one or more complications that are known to be associated with retained blood.\textsuperscript{9,10} A 2019 multi-center analysis of 30-day readmissions in 2218 cardiac surgery patients in the New England region found that among the 272 patients who were readmitted, pleural or pericardial effusion and dysrhythmia occurred in 19\% and 16\% of readmitted patients, respectively.\textsuperscript{13} Separately, a 2021 systematic review and meta-analysis of 53 studies found that dysrhythmia (4.5 - 26.7\%), and pleural effusion (0.4 - 22.5\%) were among the most frequent underlying causes of readmission in 8,937,457 coronary artery bypass grafting (CABG) patients.\textsuperscript{14} The frequency of readmissions related to these complications suggests that prevention of retained blood is a worthwhile target for improvement.

\textit{Methods for chest tube clearance}

Chest tubes are, of course, designed to reduce retained blood, but an estimated 36\% of chest tubes clog after placement, and of those, 86\% occlude beneath the skin where they are not visible.\textsuperscript{15} A published survey of cardiac surgeons and nurses found that 100\% of surgeons had seen chest tube clogging and 87\% had observed associated adverse patient outcomes;\textsuperscript{16} in fact, surgeons’ concerns about clogging were a major reason that they chose larger chest tubes, despite greater pain for patients. The ERAS Cardiac Society guidelines suggest that maintaining chest tube patency may assist with preventing complications associated with retained blood,
while both the ERAS Cardiac Society and ERAS Society/ESTS guidelines recommend against common practices such as suctioning or manually “milking” or “stripping” the tubes, as these have no documented benefit, may break the sterile field, and may damage internal tissues (Table 1).3, 4, 17

This may explain in part why one of the largest-growing segments of drainology-related clinical research has been the development of active, automated mechanisms for tube clearance. In our literature search, 37% of papers in the last 15 years referred to this subject. There have been nine clinical trials, including one with randomized design, for the device that uses a magnetic actuation system (Table 2).12, 18-26

Seven of the nine studies showed favorable results, finding an 89% relative reduction in total chest tube occlusion,12 between 55% and 72% relative reduction in reoperation for hemorrhage and tamponade,12, 20, 23 43% fewer interventions for retained blood symptoms,25 and as much as a 33% relative reduction in POAF (20% vs 30%, p=.013).18 One study demonstrated a significant reduction in delayed sternal closure,23 while findings from another included fewer procedures to drain pleural effusions, reduced ICU and postoperative LOS, and lower costs of care when active clearance was used.18

Two of the nine clinical studies did not show a benefit. In one, the authors discussed the need for additional training and compliance from the nursing staff to ensure that they were comfortable with chest tube management and used the product per-protocol on a regular basis.24 This highlights the importance of a systems and protocol-based approach to new techniques and
technologies, with training and buy-in from the nursing team, to any active process to prevent chest tube clearance.\textsuperscript{27} It further suggests a need for surgeons to continue to engage their ICU colleagues in any process developed to address this problem.

The other study that did not show a benefit was too small to draw statistical comparisons, with only 50 patients in the active tube clearance intervention arm,\textsuperscript{22} and it is therefore not surprising it did not show any benefit. The authors did observe a reduction in POAF.

Most recently, a systematic review and meta-analysis of 7003 people from eight of these nine studies concluded that incidence of reoperation and POAF were more favorable when active tube clearance was used after cardiac surgery.\textsuperscript{21} The meta-analysis also showed a reduction in re-exploration for bleeding and a reduction in pleural interventions for effusion.

An important question is whether the incremental cost of active tube clearance is justifiable. Given the reductions in complications, ICU hours, and LOS that are seen in aggregate over the over 7,000 patients treated with these devices, one could infer that the reduced overall resource utilization and healthcare expenses would justify the costs. This has been explored in one study thus far, in which 337 patients treated with active tube clearance were compared to 300 with standard drainage.\textsuperscript{18} The authors found that median costs were reduced by $1831.45 (-$3580.52, $82.38; p = 0.04) and the mean costs reduced by an average of $2696 (-$6027.59, $880.93; p=0.116). Further studies should include the reduced resource-utilization endpoints, such as time on the ventilator, time in the ICU, and LOS alongside actual measured costs. This could go a
long way to help teams make real-world decisions with economic data to help inform where the
program wants to spend its efforts to reduce costs while at the same time improving outcomes.

Another automated, device-based technology being studied for its ability to safely maintain chest
tube patency, known as “air sweep,” creates a bolus of sterile air every 5 minutes within the
chest tube, ensuring that any fluids stagnating there are swept out and into the drainage reservoir.
A small, first-in-human study of this technology in 27 non-emergent cardiac surgery patients
failed to show a benefit with only a comparable drainage profile, total output, and readmission
rates for effusion compared to 80 conventional controls. Larger studies will be needed to verify
the safety and utility of this interesting potential solution to maintaining chest tube patency.

**Digital drain systems for better decision-making**

For thoracic surgery, the ERAS Society/ESTS guidelines recommend the use of digital drainage
systems to reduce variability in decision-making. Unlike their analog counterparts, digital
systems provide a mechanism for continuously and accurately measuring intrapleural pressure
over time, the presence and magnitude of air leaks (flow in mL/min), and volume over time of
fluid drainage, allowing for both acute assessments and recognition of developing clinical
patterns. Some systems are capable of automatically maintaining a predetermined intrathoracic
pressure even when a patient is mobile, potentially enabling air-leak management on an
ambulatory or even outpatient basis. Evidence comparing the effect of digital systems versus
analog systems on air leak and chest tube duration after lung resection favors reduction in air-
leak duration and time to chest tube removal—on the order of days—when a digital system was
used.
Reduction in interobserver variability in decision-making about chest tube removal may be an important benefit of digital drainage systems, and indeed, it is a matter of some debate whether improvements observed with digital systems are a direct benefit of their variable, regulated pressure capabilities—which allow maintenance of very low and essentially passive, negative-pressure drain settings—or simply that objective data from these systems aid in more consistent treatment decisions. In either case, the outcomes are meaningful and worthy of additional study.

Meanwhile, evidence to support the utility of digital drainage systems after cardiac surgery is scarce but accruing. Three preliminary studies have suggested that digital systems are safe to use in cardiac surgery patients and are associated with reduced air leak, more efficient early drainage of the chest cavity, earlier time to drain removal, and greater satisfaction among clinical staff compared to analog drain systems. Expanding on these early findings, a presentation at AATS 2023 reported the results of a study comparing outcomes in 1,042 propensity-matched CABG patients managed with either conventional or digital drainage, but the findings have yet to be vetted through a full peer-review process.

**Number of chest tubes and timing of removal after lung surgery**

A traditional practice after lobectomy has been to insert more than one drain in the pleural space with the logic that more tubes facilitate more complete drainage of air and fluid. However, the belief that more than one chest tube is beneficial to all lung surgery patients has been refuted. While two tubes may be appropriate in specific circumstances such as a bilobectomy, the ERAS Society/ESTS guidelines recommends the use of a single chest tube after lobectomy,
noting that multiple tubes show no evidence of advantage, and use of a single tube is associated
with less pain, reduced duration of chest drainage, and a smaller volume of fluid drained.

The safety and advantages of earlier chest tube removal after pulmonary resection have also been
demonstrated. A study of 100 thoracoscopic lobectomy and segmentectomy patients found that
when chest tubes were removed on postoperative day 0 according to prespecified criteria, 45% of
patients were eligible with no reinsertions for pneumothorax while encountering one readmission
for delayed pleural effusion.\textsuperscript{41} Similarly, a recent, randomized controlled trial suggests early
removal, regardless of volume, is associated with shorter duration of drainage and non-inferior
outcomes.\textsuperscript{42} Compliance with opioid-free analgesic protocols was significantly higher (75% vs
45%, p=0.004) in patients with early removal, consistent with earlier findings showing that static
and dynamic pain scores and ventilatory function improve after chest tube removal.\textsuperscript{43} The ERAS
Society/ESTS guidelines suggest that, for thoracic surgery and pulmonary resections, chest tubes
should be removed when daily serous effusion is $\leq 450$ mL/24 h of non-hematic, non-chylous
fluid (Table 1).

In cardiac surgery, it is less clear if rapidly removing chest tubes is equivalent or superior to
leaving them in longer. There are two studies showing that pericardial and pleural effusions
might be higher when the tubes are removed in an expedited fashion.\textsuperscript{44,45} It is likely that it is
more complex than just how long tubes remain in place. Future studies should consider the entire
strategy of reducing retained blood as early as possible to prevent any residual blood around the
heart and lungs that can be a nidus for inflammatory effusion production in the ensuing days.
Thus, looking at studies, alone or combined with specific strategies to reduce retained blood may
be a facilitating factor in making early chest tube removal safer and less likely to cause a higher effusion rate later. The entire perioperative care team should be working on a reduction of retained blood strategy in the early hours after surgery, and then test if the tubes can come out safely sooner to facilitate earlier ambulation and other benefits associated with this approach.

Questions to be addressed in future guidelines

Standard chest drain routines after cardiac surgery: One tube, one cut, one day, one way?

Aside from patency, the ERAS Cardiac Society guidelines currently lack recommendations to support standardized practices for chest drainage after cardiac surgery. However, development of an effective, evidence-based algorithm that specifies a standard for the materials, sizes, type, and number of drains, posterior pericardiotomy, use of digital drain technology, and duration of therapy could be a powerful means to improve postoperative outcomes. We expect to see new recommendations regarding these questions in future guidelines and expert consensus documents.

For example, a presentation at the 2023 meeting of the European Association for Cardio-Thoracic Surgery titled, “One Tube? One Day?” related evidence supporting use of a single tube and early removal, together with posterior pericardiotomy (“One Cut”), as a proposed standard practice in postoperative care. The proposal to recommend use of a single tube came from an analysis of 5,698 cardiac surgery patients that found no difference in rates of reoperation for hemorrhage or tamponade, ICU LOS longer than 48 h, postoperative LOS greater than 9 days, or mortality when two chest tubes were placed instead of one. Another study published in 2019 examined the effect of using an extended drainage protocol (removal on postoperative day 2 with
< 50 mL drainage in 4 h, versus on postoperative day 1 with <50 mL drainage per hour, respectively) for cardiac surgery patients and found that rates of late tamponade were reduced (3.6% vs. 8.8%), but extended drainage had no effect on other complications.

Posterior pericardiometry drainage is another focus of interest. A systematic review and meta-analysis of 19 RCTs (3,425 patients) by Gozdek and colleagues found that posterior pericardial drainage was associated with a 58% reduction in POAF (p<0.001), 90% reduction in the odds of cardiac tamponade (0.42% vs 4.95%; OR (95% CIs) 0.13 (0.07–0.25); p<0.001), and significant reductions in early and late pericardial effusion, LOS, and odds of mortality or cardiac arrest. More recently, in 2021 Gaudino and colleagues published the results of the “Effect of Posterior Pericardiotomy on the Incidence of Atrial Fibrillation After Cardiac Surgery” (PALACS) RCT. In this adaptive, single-center, single-blind trial in 420 patients undergoing selected cardiac surgical procedures, posterior left pericardiotomy reduced the incidence of POAF by 47% (17% vs 32%, p=0.0007; adjusted OR 0.44 [95% CI 0.27–0.70], p=0.0005) without an increase in 30-day postoperative complications. An extension of the trial, which will evaluate the effect of posterior left pericardiotomy on 5-year clinical outcomes, is ongoing (NCT05903222).

Continuous postoperative pericardial flushing

Finally, another novel technique that may be worthy of addressing in future guidelines is continuous postoperative pericardial flushing (CPPF). First described in 2015 in 21 adult patients undergoing surgery for congenital heart disease, the technique involves continuous, volume-controlled irrigation of the pericardial space after sternal closure with warm saline, which is introduced through an inflow tube placed into the same incision as the pericardial drain.
This study, along with a second pilot study in 42 CABG patients, found that CPPF was associated with a clinically meaningful reduction in postoperative blood loss.\textsuperscript{52} An RCT published in 2020 confirmed that, compared to standard drainage, CPPF improved chest tube patency, reduced blood loss, and reduced pleural effusion in 170 adult patients undergoing surgery for valvular or congenital heart disease,\textsuperscript{53} and a second RCT in 169 CABG patients found that CPPF therapy reduced median postoperative blood loss by 76% compared to standard drainage (p=0.001).\textsuperscript{51} Bleeding-related complications such as reoperation for hemorrhage and cardiac tamponade were also reduced, with comparable costs and QOL.

This strategy to reduce retained blood seems promising, but readers are cautioned that these studies are small. The technology is as-yet untested for potential complications such as chest tube clogging with the fluid being infused, and there are no products with regulatory approval on the market as yet. However, the results to date further validate the hypothesis that strategies to reduce retained blood can be helpful, and suggest that further studies are needed to examine this approach for safety and efficacy at a larger scale.

**Comments and conclusion**

Currently, the surgical community is far from consensus regarding the optimal type, location, or number of chest tubes and their postoperative duration, much less whether or not new technologies and devices can offset their own costs or provide overall, net-positive economic value by preventing avoidable adverse outcomes.\textsuperscript{55} However, greater awareness of this expanding field of drainology should encourage practitioners to update their understanding of
new evidence, evaluate and question their traditional routines, study the effects of changes and standardization, and scrutinize and share their results for the benefit of others.

An exemplary effort in this regard is the work of Bates and colleagues, published in 2020 and 2021.\textsuperscript{56,57} As part of a rigorous quality improvement initiative, this group first surveyed chest tube management practices (chest tube removal criteria) and measured outcomes (chest tube duration, chest tube reinsertion, readmission for pleural effusion, and LOS) after congenital cardiac surgery in 1,029 patients at nine centers.\textsuperscript{56} The results of that effort engendered an ongoing collaborative learning project between the nine centers, in which best practices identified from the center with the most favorable outcomes were used to create practice standards. In the follow-up publication, documented improvements were observed across centers in mean chest tube duration and LOS without increasing complications.\textsuperscript{57} A similar, community-wide commitment to generation of evidence and creation of standard practices based on the results will gradually reduce practice variability and improve quality of care for our patients.

\textbf{ACKNOWLEDGMENTS}

The authors thank Katherine A. Lobdell for editorial assistance and Jeanne McAdara PhD of Biolexica, LLC for professional assistance with manuscript preparation, which was funded by Medela. The authors maintained full freedom of investigation and control over manuscript content.
REFERENCES


### Table 1: Evidence-based recommendations for chest-tube management

<table>
<thead>
<tr>
<th>ERAS Cardiac Society Recommendations</th>
<th>Evidence Level/Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance of chest tube patency to prevent retained blood is recommended</td>
<td>B-nonrandomized studies/Class I</td>
</tr>
<tr>
<td>Stripping or breaking the sterile field of chest tubes to remove clots is not recommended</td>
<td>A/Class III (no benefit)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ERAS Society and ESTS Joint Recommendations</th>
<th>Evidence Level/Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routine external suction of chest drains should be avoided</td>
<td>Low/Strong</td>
</tr>
<tr>
<td>Digital drains should be used to reduce variability in decision-making</td>
<td>Low/Strong</td>
</tr>
<tr>
<td>Chest tubes should be removed even if the daily serous effusion is high (up to 450 mL/24 h)</td>
<td>Moderate/Strong</td>
</tr>
<tr>
<td>A single tube should be used instead of 2 after anatomical lung resection</td>
<td>Moderate/Strong</td>
</tr>
</tbody>
</table>

FIGURE LEGENDS

Figure 1: Chest drain management in thoracic and cardiac surgery: different challenges but same need for standardization.

Figure 2: PRISMA literature search, disposition of results
Drainology: The Science of Chest Drain Management

- Identify Knowledge Gaps
- Generate Evidence
- Establish Standard Practices
- Review Outcomes
- Update Guidelines

Retained Blood Complications
Persistent Air Leak
Drainology: The Science of Chest Drain Management

- Identify Knowledge Gaps
- Generate Evidence
- Establish Standard Practices
- Review Outcomes
- Update Guidelines

Retained Blood Complications
Persistent Air Leak
3069 studies imported for screening

2878 studies screened

460 full-text studies assessed for eligibility

311 studies included

191 duplicates removed

2418 studies irrelevant

149 studies excluded

- 45 Wrong intervention
- 39 Trauma/emergency setting
- 38 Pediatric population
- 26 Wrong indication
- 1 Manuscript retracted
SUPPLEMENTAL APPENDIX

Studies included after PRISMA review


Dixon B, Reid D, Collins M, Newcomb AE, Rosalion A, Yap CH, et al. The operating


85. Ema T, Neyatani H, Yamamoto S, Iizuka S, Funai K, Shiiya N. Computed tomography-guided tube thoracostomy for massive subcutaneous emphysema following lung


113. Holbek BL, Christensen M, Hansen HJ, Kehlet H, Petersen RH. The effects of low


141. Kruse T, Wahl S, Guthrie PF, Sendelbach S. Place Atrium to Water Seal (PAWS):


225. Royer AM, Smith JS, Miller A, Spiva M, Holcombe JM, Headrick JR. Safety of


267. Tavlasoglu M, Kurkluoglu M, Gurbuz HA, Durukan AB. The fanfolding modification for


SUPPLEMENTAL REFERENCES


