

Abdominal Wall Expanding System Obviates the Need for Lateral Release in Giant Incisional Hernia and Laparostoma

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Abstract

Background: In large incisional hernias and after laparostoma midline closure may be impossible. A novel abdominal wall expander system (AWEX) is proposed and evaluated. **Methods:** In patients with large incisional hernias and laparostoma where primary midline closure was impossible, AWEX was used. Patients undergoing abdominal wall reconstruction using AWEX between May 2012 and December 2015 were included. Intraoperative the abdominal wall was stretched by attaching the midline fascia borders to a retraction system under tension for 30 minutes. Length and width of the hernia defect were measured in preoperative computed tomography. Width gain after AWEX procedure, operative time, morbidity, and presence of remaining midline gap was evaluated. Patients were followed for hernia recurrence. **Results:** Ten patients with incisional hernias (N = 4) and grafted laparostoma (N = 6) underwent abdominal wall reconstruction using AWEX. Median (interquartile range) length and width of the hernia defect was 18.0 (15.0-20.5) and 12.0 (11.8-13.3) cm. Width gain after AWEX was 8.5 (8.0-10.5) cm. Operative time was 270 (135-379) minutes. The major morbidity was 20%. In 4 patients a gap of 4 (4-5) cm was bridged by intraperitoneal onlay mesh. After a median follow-up of 21 (7-36) months no hernia recurrence was observed. **Conclusions:** Stretching of the abdominal wall that has been shown successful using progressive restressed retention sutures and progressive preoperative pneumoperitoneum is reduced from days and weeks to 30 minutes in AWEX. AWEX is a promising alternative to component separation in repair of large incisional hernias. After refinement of the system prospective evaluation is required.

Keywords

hernias, colorectal surgery, evidence-based medicine/surgery

Introduction

The reconstruction of the abdominal wall in giant incisional hernia and after split-skin grafted laparostoma is still challenging. Once the midline of the abdominal wall is opened the anterolateral muscles rapidly get retracted. It becomes difficult to re-approximate the fascial borders. Therefore, the most demanding step in reparation of large hernias is the midline closure of the fascia. Commonly, in surgery for incisional hernias it is aimed at closing the anterior and posterior rectus sheet directly and adding reinforcement with a mesh in retromuscular sublay or intraperitoneal onlay position. However, in case of a large hernia defect this may be impossible, as the abdominal wall cannot be mobilized to cover the defect. Lateral release with component separation offers additional gain of the abdominal wall up to 3 to 5 cm on each side.^{1,2} By modification of the component separation technique even larger defects, measuring up to 20 cm at the level of the

umbilicus, may be covered and thus midline closure enabled.³ However, patients undergoing abdominal wall reconstruction by component separation suffer from an impaired quality of life. In a long-term assessment, a decreased physical functioning and a high prevalence of depression and posttraumatic stress disorder was found after a follow-up between 9 months and 15 years.⁴ The abdominal wall muscles remain lateralized and lead to a weakness of the abdominal muscles. Moreover, owing to the large wound area, the postoperative morbidity ranges between 23% and 100% and includes severe wound

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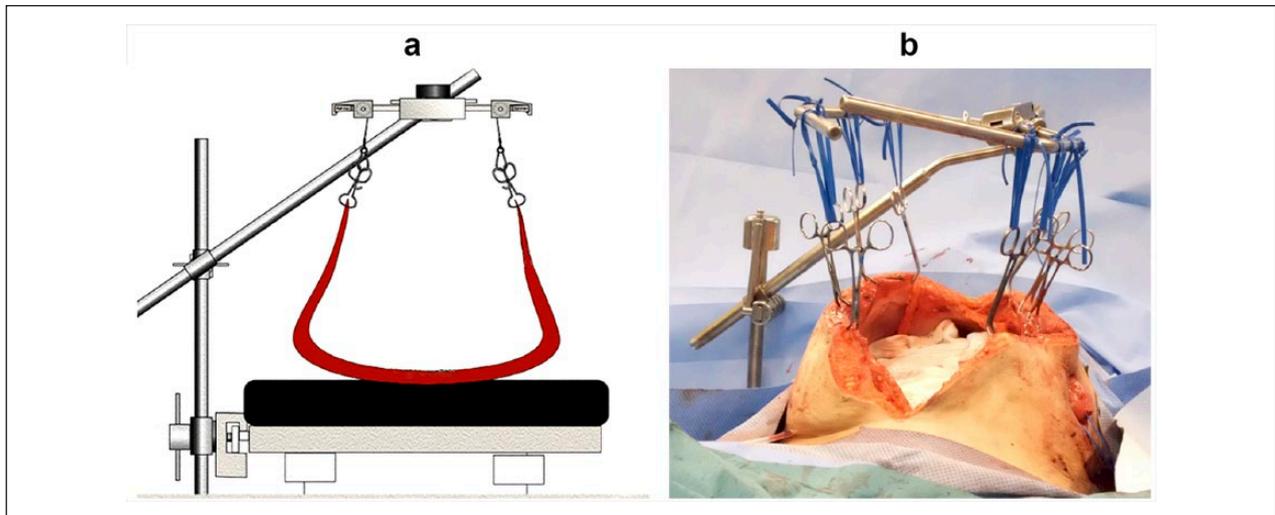


Figure 1. (A) Principle of abdominal wall expander system (AWEX). (B) Intraoperative setting.

complications, skin necrosis, hematoma, and pulmonary complications.⁵ The hernia recurrence rate lies between 5% and 53% after 15 to 52 months.⁶ If midline closure of the fascia is not achieved, intraperitoneal onlay mesh repair is used and the gap in the abdominal wall is bridged with prosthetic material.

In this study, acute intraoperative stretching of the abdominal fascia using a novel abdominal wall expander system (AWEX) is proposed. The results of abdominal wall reconstruction using this novel system in the first patients are evaluated.

Methods

In patients with large incisional hernias and laparostoma where primary midline closure was impossible, AWEX was used. Consecutive patients undergoing abdominal wall reconstruction using AWEX between May 2012 and December 2015 were included in this study. The analysis of data was performed in a retrospective manner.

The indication for abdominal wall reconstruction using AWEX was laparostoma and large incisional hernias in which the fascia borders could not be approximated with ease after adhesiolysis and hernia reduction. The indication for AWEX was made intraoperative.

Setup and Surgical Technique

The idea behind AWEX is the acute, intraoperative stretching and mobilization of the abdominal wall while the patient is under general anesthesia. During the procedure the muscles of the patient were relaxed at the maximum. After laparotomy and a complete adhesiolysis of the bowel the midline fascial borders were exposed. If

primary closure of the fascia was felt intraoperatively impossible AWEX was used. A stable abdominal retractor (Omni-Flex, Integra Life Science, Plainsboro, NJ) with 2 height-adjustable arms was mounted. The arms were positioned about 20 cm above the abdominal wall of the patient. Backhaus towel clamps were used to grasp the fascial borders on both sides. Large vessel loops were knotted on the towel clamps and they were attached to the arms of the abdominal retractor under maximum tension (Figure 1). After a few minutes the vessel loops were restressed when tension has reduced. The stretching of the abdominal wall was maintained for 30 minutes. After the stretching a reconstruction of the abdominal wall using a mesh-reinforcement was performed according to the individual size and localization of the hernia.

Evaluation

Patients being treated using AWEX were identified in the electronic operative reports. For patient's characteristics age, gender, body mass index (BMI), and type and number of previous abdominal operations were collected. The type of hernia was classified according to the classification of the European Hernia Society (EHS).⁷ The length and width of hernia opening were measured intraoperative under full relaxation. Intraoperative the width gain after AWEX was measured using a ruler. The duration of the procedure, intraoperative complications, postoperative morbidity classified according to Clavien-Dindo,⁸ blood transfusions, length of stay, extent of midline closure or width of remaining defect, type and size of used prosthesis for mesh reinforcement, and position of mesh were gathered. Any changes of AWEX technique and management were noted. Duration of follow-up and a

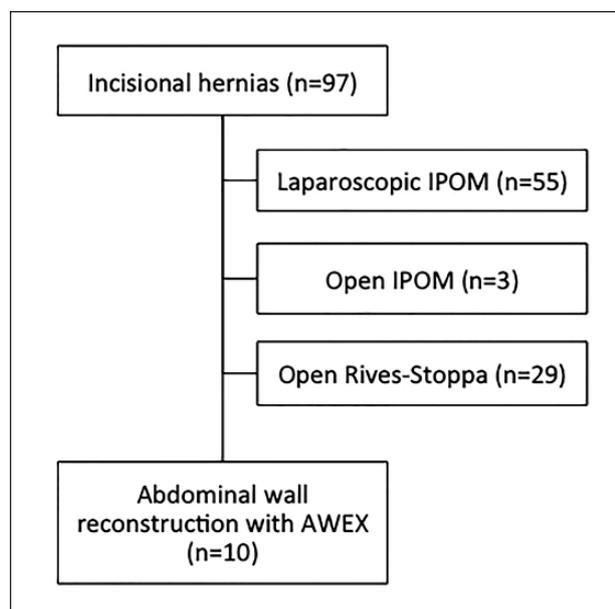


Figure 2. Flow chart of included and excluded patients (IPOM, intraperitoneal onlay mesh).

narrative report of persisting complaints in the follow-up as well as evaluation of recurrent hernias were assessed. All patients were evaluated for hernia recurrence by abdominal ultrasonography by the surgeon. All patients' data were collected in the German hernia registry (Herniamed).

Statistics

For statistical analysis GraphPad Prism version 6.00 for Mac (GraphPad Software, La Jolla, CA) was used. Median with interquartile range was calculated for all numerical data. Proportions between groups were compared using a 2-tailed Mann-Whitney test assuming a nonparametric distribution. Categorical variables were compared using a 2-sided Fisher's exact test. A 2-sided P value $\leq .05$ was considered to be statistically significant.

Results

Patient's Characteristics

During the study period, 97 patients underwent incisional hernia repair. Of those 55 were treated by laparoscopic intraperitoneal onlay mesh repair with midline suture closure, 29 by open repair and mesh reinforcement in sublay-position (Rives-Stoppa), and 3 by open repair and reinforcement by intraperitoneal onlay mesh (Figure 2). In none of the aforementioned patients a lateral release or other method of abdominal wall enlargement was applied.

A total of 10 patients underwent abdominal wall reconstruction using AWEX. Three female and 7 male patients with a median age of 68 (57-75) years were included. The median BMI was 27 (24-31) kg/m^2 . The indications for abdominal wall reconstruction were incisional hernia ($N = 4$) and laparostoma ($N = 6$). The type of abdominal wall defect, previous surgery, classification of hernia according EHS, and width and length of the hernia defect as measured intraoperative are shown in Table 1.

Procedure Characteristics

The median duration of surgery was 270 (135-379) minutes. In 3 cases additional procedures were performed beside adhesiolysis and abdominal wall reconstruction. Two patients underwent a previous left sided colectomy for ischemia with establishment of a Hartmann's situation. In both a restoration of the intestinal continuity was performed, and in one of those patients the anastomosis was protected by a loop ileostomy. The description of performed surgery, width gain after AWEX, type, position and size of used mesh for reinforcement, and the morbidity classified according Clavien-Dindo are depicted in Table 2. The only intraoperative complication was an enterotomy during adhesiolysis in a patient with a Billroth II reconstruction. This resulted in the need for redo of the Billroth II reconstruction. In 4 patients it was not possible to close the midline. The remaining defect measuring 4 (4-5) cm in median was bridged by mesh-implantation. Patients necessitating a bridging had a larger width of the defect than those where the midline could be closed (13.5 [12.3-15.5] cm vs 12 [11-12] cm, $P = .02$). In all patients with a laparostoma mesh-reinforcement by intraperitoneal onlay-mesh was performed, whereas incisional hernias were reinforced using a mesh in retromuscular sublay position according Rives-Stoppa. In order to replace the missing part of the abdominal wall in 3 out of 4 patients with a laparostoma a combination of a biological mesh (Strattice, Acelity, San Antonio, TX) and a partially absorbable lightweight mesh (Ultrapro, Johnson & Johnson Inc, New Brunswick, NJ) was used. In the fourth laparostoma patient only a biological mesh was used. The biological mesh is derived from porcine skin that was processed and preserved in a phosphate-buffered aqueous solution with matrix stabilizers. Both meshes were sutured together in a "mesh-sandwich" technique. The part with the biological mesh was put toward the intestine and the synthetic mesh toward the subcutaneous tissue in the zone of bridging. In the first 5 patients the fascia was stretched toward the contralateral side, whereas in the following 5 patients the fascia was stretched in an upright direction during the AWEX procedure (Figure 3A). The overall and major (\geq IIIb) complication rate was 40% and 20%. Wound complications

Table 1. Age of Patient, Type of Abdominal Wall Defect, Previous Surgery, and Width and Length of Defect (Intraoperative Measurement in Full Relaxation, in cm).

No.	Previous Surgery	Type	EHS Class	Defect Size	
				Width	Length
1	Burst abdomen due to small bowel leakage after laparotomy for small bowel obstruction	Laparostoma	M2-4 W3	11	18
2	Distal gastrectomy with Billroth-II reconstruction	Laparostoma	M2-4 W3	12	25
3	Replacement of ruptured aortic aneurism and discontinuity sigmoidectomy for ischemia	Laparostoma	M2-5 W3	12	22
4	Discontinuity sigmoidectomy for perforation and subsequent restoration of intestinal continuity	Incisional hernia	M3-5 W3	14	18
5	Sigmoidectomy for perforation, aorto-iliac replacement for aneurism, small bowel resection, failed abdominal wall reconstruction	Laparostoma	M2-4 W3	13	15
6	Right hemicolectomy for ischemia after heart surgery	Incisional hernia	M1-3 W3	12	15
7	Burst abdomen after Wertheim surgery for ovarian cancer	Laparostoma	M2-4 W3	16	18
8	Subtotal colectomy for ischemia, multiple relaparotomy and laparostoma for abdominal sepsis	Laparostoma	M3-5 W3	12	20
9	Multiple laparotomy for gastrointestinal bleeding	Incisional hernia	M2-4 W3	12	20
10	Right hemicolectomy for adenocarcinoma (pT3 pN1)	Incisional hernia	M2-3 W3	11	12

Abbreviation: EHS, European Hernia Society.

occurred in 20%. The median postoperative length of stay was 14 (11-18) days (Table 2).

After a median follow-up of 21 (7-36) months there were no hernia recurrences. In one patient there was a persisting, but asymptomatic, subcutaneous seroma 1 month after surgery. This was clinically observed without further intervention. In another patient there was a slight bulging in the midline after bridging of a large defect after laparostomy. However, there was no evidence for hernia recurrence. As an example, preoperative incisional hernia and the situs 4 months after surgery for patient number 3 is shown in Figure 3.

Discussion

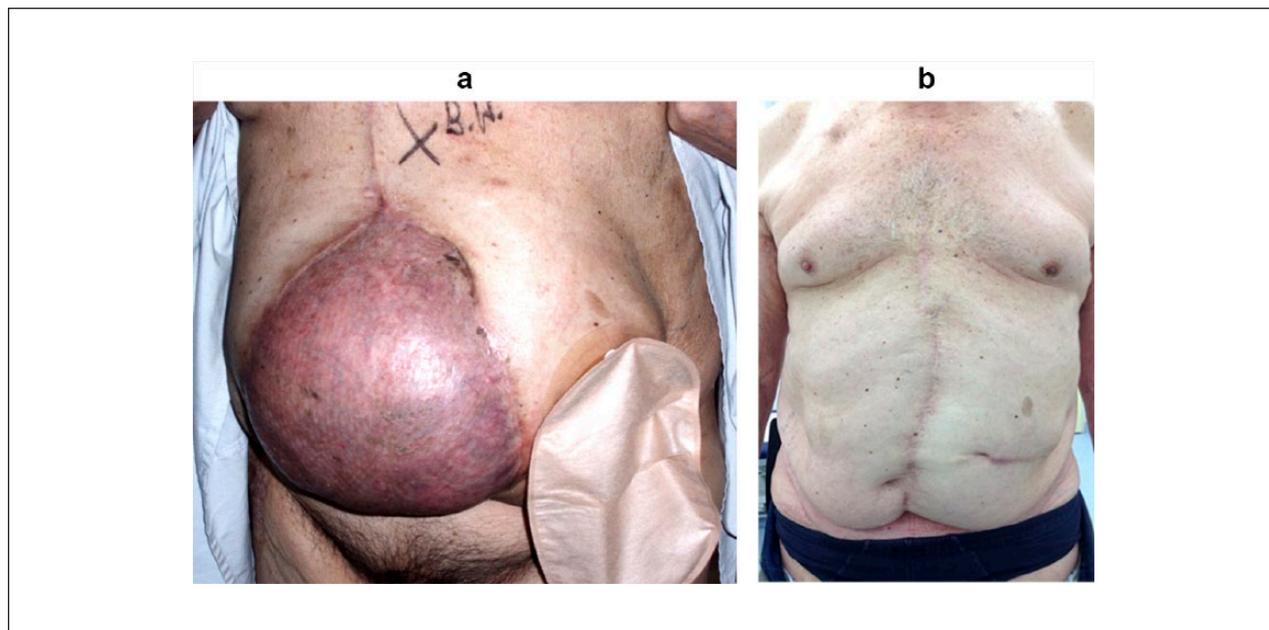
The successful development and use of a novel system for acute, intraoperative stretching of the retracted abdominal wall during abdominal wall reconstruction in incisional hernias has been demonstrated in this study. The achieved gain in width after stretching the fascia for 30 minutes of 8.5 cm is comparable to what may be expected after traditional component separation. In the further clinical course no signs of abdominal compartment were observed and none of the patients developed a burst abdomen. The novel system allows omission of component separation necessitating an extensive dissection of the abdominal wall and altering the anatomy. Two patients (20%) developed a subcutaneous seroma, but no other wound or parietal complication was found.

Complex incisional hernias are defined by a loss of intraabdominal domain.^{9,10} Once the integrity of the midline is broken the anterolateral abdominal wall muscles lose their natural attachments. The muscles not under tension become rapidly retracted. Consequently, the abdominal wall gets too short to be closed in the midline and intraperitoneal organs lose their intraabdominal domain. Fascia retraction may happen in giant incisional hernia but also in the acute setting during open abdomen treatment (OAT). In OAT for acute abdominal sepsis the use of retention sutures attached to the fascia under tension and restressed every 2 to 3 days gradually allow the closure of the fascia.¹¹ In a randomized controlled trial comparing fascia closure in vacuum-assisted closure (VAC) for OAT with and without the use of retention sutures fascia closure was achieved in 14 out of 15 patient in the retention suture group and in only 6 out of 15 patients without retention sutures.¹² Retention sutures were applied for a mean of 8 days. A system for approximating the abdominal fascia, which allows restressing the retention sutures outside of the operation room and without narcosis, is the abdominal re-approximation anchor system (ABRA, Clanica Design Inc, Almonte, Ontario, Canada). In a randomized controlled trial using ABRA and VAC versus VAC only the number of operation room trips was significantly reduced. The median time to fascia closure was 9.5 days.¹³ Retention sutures basically lead to a stretching of the abdominal wall and reverse the retraction of the anterolateral muscles by myofascial release

Table 2. Procedures, Width Gain After Fascia Stretching Using Abdominal Wall Expander System (AWEX), Used Mesh, Size of Mesh, Presence and Extent of Bridging, and Morbidity Classified According Clavien-Dindo.

No.	Procedures	Length Gain, cm	Mesh Type	Mesh Size, cm	Mesh Position	Bridging, cm	Morbidity	Morbidity Class
1	AWR/AWEX	8	Strattice	25 × 20	IPOM	No	Respiratory decompensation	2
2	AWR/AWEX, re-reconstruction of Billroth-II, cholecystectomy, appendectomy	N/A	Strattice/ Ultrapro	30 × 20	IPOM	No	Pneumonia Delirium, atrial fibrillation, wound revision for seroma	3b
3	AWR/AWEX, restoration of bowel continuity, loop ileostomy	N/A	Strattice	25 × 20	IPOM	No	—	0
4	AWR/AWEX	10	Ultrapro	40 × 20	Sublay	4	—	0
5	AWR/AWEX	8	Strattice/ Ultrapro	25 × 20	IPOM	4-5	—	0
6	AWR/AWEX, cholecystectomy	N/A	Strattice/ Ultrapro	30 × 20	IPOM	No	Relaparotomy for bile leakage	3b
7	AWR/AWEX	12	Strattice/ Ultrapro	40 × 20	IPOM	5	Seroma	I
8	AWR/AWEX, restoration of bowel continuity	N/A	Strattice/ Ultrapro	40 × 25	IPOM	3-4	—	0
9	AWR/AWEX	8-10	Ultrapro	30 × 15	Sublay	No	—	0
10	AWR/AWEX	8	Ultrapro	30 × 15	Sublay	No	—	0

Abbreviations: AWR, abdominal wall reconstruction; IPOM, intraperitoneal onlay mesh.

**Figure 3.** Giant incisional hernia (A) preoperatively and (B) 4 months after abdominal wall reconstruction using the abdominal wall expander system in patient no. 3.

and relaxation. A similar effect is achieved by progressive preoperative pneumoperitoneum (PPP) in incisional hernia. In an observational study on 18 patients an increase in anterolateral muscle width of 3 cm per side was found.¹⁴ However, PPP not only increases the muscle and fascia width but also the size of the incisional hernia itself. Despite this fact, successful surgical reintegration has been reported in 93% to 100% and primary fascia closure in 94% of cases.¹⁵ PPP, however, induces a restrictive respiratory syndrome and needs insufflation for a median of 10 to 17 days, which prolongs hospitalization significantly.¹⁶ Recently, botulinum toxin injection into the lateral abdominal wall muscles prior to hernia repair has been proposed. With a pretreatment of 1 month a width gain of 5 cm has been reported.¹⁷

As in PPP, restressed retention sutures and botulinum toxin pretreatment AWEX aims at reversing the retraction of the anterolateral muscles of the abdominal wall. However, AWEX allows reducing the time for stretching fascia and muscles from days or weeks to only 30 minutes. It suggests an intraoperative and acute model of fascia mobilization. The current series of the first 10 patients being treated by AWEX showed the feasibility of this concept and allowed successful reintegration of the hernia content into the abdominal cavity enabling abdominal wall reconstruction. AWEX was used selectively in 10 out of 97 patients that underwent incisional hernia repair during the study period. In all of the remaining patients the midline could be closed without component separation. Yet the idea of AWEX are still in an early phase of development (IDEAL stage 2a).¹⁸ Further studies should focus on prospective quantification of the width gain of the anterolateral muscles measured in pre- and postoperative computed tomography. While in the current study no signs of increased abdominal pressure including unusual pain, occurrence of burst abdomen or impaired organ function were found, the sustainability of muscle stretching should be assessed by monitoring the bladder pressure before and after surgery.

In this study in most of the patients with a laparostoma for mesh-reinforcement a combination of a biological mesh and a partially absorbable mesh was used. The idea behind this was to replace the missing abdominal wall with a matrix for collagen ingrowth and at the same time reinforce the abdominal wall with a synthetic mesh to reduce the risk of hernia recurrence after absorption of the biological mesh. However, this concept needs further evaluation and is not investigated in the present study.

The current study is limited by its retrospective nature and the small sample size. Moreover, there is heterogeneity in type and sizes of abdominal wall defects. The AWEX procedure is still in a development stage. During the study period the direction of tension was changed from traction toward the contralateral side to an upright direction. It was assumed that upright distension leads to

a more effective mobilization of the retracted anterolateral abdominal muscles. However, the study reproducibly showed the feasibility of acute stretching of retracted abdominal wall with a constant width gain. Based on this proof of principle refinements of the system may be performed. Currently, the authors are developing an improved system for AWEX. This system should allow more stable and steady tension on the fascia, easy restressing of the tension, and allow modification of the direction of movement. Moreover, the tension applied on the abdominal wall should be limited using torque control. A patent has been granted to the authors (DE and AZ) for such a system (European Patent No. 15179264.5-1654).

In conclusion, AWEX is a promising novel concept allowing intraoperative and acute stretching of the abdominal wall and thus enabling reconstruction in large incisional hernia as well as in laparostoma. AWEX may represent an alternative to PPP and to component separation and should be evaluated against these establishment concepts.

Authors' Note

Informed consent was obtained from all individual participants included in the study. All procedures performed were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Author Contributions

All authors gave their final approval of the current version to be published. All authors agree that they are accountable for all aspects of the work.

Study concept and design: Dietmar Eucker, Andreas Zerz, Daniel C. Steinemann

Acquisition of data: Dietmar Eucker, Daniel C. Steinemann

Analysis and interpretation: Dietmar Eucker, Daniel C. Steinemann

Study supervision: Andreas Zerz

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: DCS declares no conflict of interest. AZ and DE declare no conflict of interest. However, a European patent for an improved system for AWEX has been issued to AZ and DE (Patent No. 15179264.5-1654).

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