Surgical-site infection after abdominal wall closure with triclosan-impregnated polydioxanone sutures: Results of a randomized clinical pathway facilitated trial (NCT00998907)

Christoph Justinger, MD,[a] **Jan Erik Slotta, PhD,**[b] **Sebastian Ningel,**[c] **Stefan Gräber, MD,**[d] **Otto Kollmar, MD,**[b] *and* **Martin Karl Schilling, MD, FRCS,**[e] *Karlsruhe, Göttingen, and Homburg/Saar, Germany, and Lucerne, Switzerland*

Background. *Wound infections after abdominal surgery are still frequent types of nosocomial infections. Suture materials might serve as a vehicle for mechanical transport of bacteria into the surgical wound. To prevent the contamination of suture material in surgical wounds, triclosan-coated suture materials with antibacterial activity was developed. We here report a prospective randomized pathway controlled trial investigating the effect of triclosan impregnation of polydioxanone sutures used for abdominal wall closure on the rate of surgical-site infections.*

Patients and methods. *A total of 856 patients included in this trial underwent a standardized clinical pathway documented abdominal wall closure after abdominal surgery. Patients were randomized to have the fascia closed with either a 2-0 polydioxanone loop or a triclosan impregnated 2-0 polydioxanone loop. The primary outcome was the number of wound infections. Risk factors for poor wound healing were collected prospectively to compare the two groups.*

Results. *When a PDS loop suture for abdominal wall closure was used, 42 (11.3%) patients with wound infections were detected. The number of patients with wound infections decreased significantly to 31 when the PDS plus for abdominal wall closure was used (6.4%, $P < .05$). Other risk factors for the development of side infections were comparably in the two groups.*

Conclusion. *This clinical pathway facilitated trial shows that triclosan impregnation of a 2-0 polydioxanone closing suture can decrease wound infections in patients having a laparotomy for general and abdominal vascular procedures. (Surgery 2013;154:589-95.)*

From the Departments of General and Visceral Surgery,[a] *Städtisches Klinikum Karlsruhe, Karlsruhe; General and Visceral Surgery,*[b] *University of Göttingen, Göttingen; General, Visceral, Vascular and Paediatric Surgery,*[c] *University of the Saarland, Homburg/Saar; Informatics and Biostatistics,*[d] *University of the Saarland, Homburg/Saar, Germany; and Hirslanden Clinic St. Anna,*[e] *Lucerne, Switzerland*

Surgical-site infections (SSIs) are among the most common health care–associated complications. They contribute to secondary patient morbidity and mortality and significantly increase the cost of care.[1-3] Several patient- and care-related risk factors for SSIs have been identified in retrospective case series as well as in prospective clinical trials. Adequate antibiotic prophylaxis and skin scrub,[4,5] the maintenance of a physiological body temperature,[6,7] or oxygen supplementation[8,9] were shown to decrease SSIs in various surgical settings. Interestingly, the combined application of those factors in care bundles, however, failed to demonstrate an effect on the overall incidence of SSIs on a national scale.[10] Reasons for that failure are far from clear but might include a low overall incidence of SSIs in general surgery, inadequate surveillance tools to detect SSIs, and observer variance in the detection of surgical complications of up to 30%.[11]

As early as the 1970s, surgical implants were impregnated with antibacterial substances. Triclosan,

This trial was funded by a restricted grant (Johnson&Johnson, Summerville, NJ).

Accepted for publication April 3, 2013.

Reprint requests: Martin Karl Schilling, MD, FRCS, Hirslanden Clinic St. Anna, St. Anna Str. 32, 6005 Lucerne, Switzerland. E-mail: martin.schilling@hirslanden.ch.

http://dx.doi.org/10.1016/j.surg.2013.04.011

a trichlorophenolic antiseptic with a wide use in consumer products, is the latest antibacterial agent used in coating or impregnation of surgical sutures. It demonstrated good bactericidal properties against many SSI-relevant bacteria in preclinical studies[12] and decreased wound infections in several randomized trials.[13,14] Other studies failed to demonstrate a protective effect either due to under powering of the trial[15] or due to a lack of control of confounding factors of wound infections.[16]

Clinical pathways have been developed to standardize medical and surgical diagnosis and treatment. When applied as a strategic care tool and used in a consistent manner, they are able to incrementally improve outcome in patients receiving advanced care—like cardiac surgery.[17] Furthermore, we and others have demonstrated that electronic documentation of the various steps of clinical pathways and controlled alteration of a singular step within a pathway allow for large-scale clinical studies at minimal costs.[18-20] We here report a prospective randomized pathway controlled trial (NCT00998907) in which we investigated the effect of impregnating, with triclosanim, polydioxanone sutures used for abdominal wall closure on the rate of SSIs.

PATIENTS AND METHODS

This prospective, double-blind randomized trial was approved by the local ethical committee and was registered as a clinical trial as NCT00998907. Starting in September 2009, all patients scheduled to undergo a laparotomy were screened for this trial. After giving written informed consent, all patients included in the trial underwent a standardized clinical pathway documented abdominal wall closure after abdominal surgery.

Patients were randomized in blocks of 50 to 100 patients to have the fascia closed with either a 2-0 polydioxanone loop (PDS II, 150 cm; Ethicon GmbH, Norderstedt, Germany) or a triclosan impregnated 2-0 polydioxanone loop (PDS Plus, 150 cm; Ethicon GmbH). Surgeons, patients, as well as wound monitors were blinded towards the use of either PDS II or PDS Plus. PDS II and PDS Plus sutures cannot be distinguished from each other in terms of physical properties such as color, feel of the suture, or tying properties. The primary end point was an SSI at the laparotomy incision during the hospital stay and follow-up within 2 weeks after discharge from the hospital.

Patients with previous methicillin-resistant *Staphylococcus aureus* contamination or patients at risk for methicillin-resistant *Staphylococcus aureus* contamination were screened preoperatively and decontaminated, if elective procedures were planned.[21] All patients undergoing colorectal resections had a preoperative bowel preparation with 3 L of prepacol (Prepacol; Guerbert GmbH, Sulzbach/Taunus, Germany). All patients had a regular shower without iodine within 24 hours before surgery followed by an abdominal wall hair removal.[22] All patients received antibiotic prophylaxis (standard antibiotics: metronidazole and ceftriaxone; metronicazole and clindmycin in case of allergy) within 60 minutes before the skin incision.[23]

After skin disinfection with a polyvidon-iodine, propran-1-ol solution (Braunoderm, B. Braun, Melsungen, Germany), the skin was incised with a scalpel. Subcutaneous tissue, the fascia, and peritoneum were dissected with an electric knife. A skin drape[24] was used in all patients, and wound edges were protected with surgical swaps. In patients with a contaminated abdominal cavity, those swaps were soaked in diluted polyvidone iodine solution. Patients having procedures lasting longer than 4 hours received a second dose of antibiotics.[23] Temperature was kept above 35°C in all patients with a warming device (Warm-Touch; Mallinckrodt Medical, Hennef/Sieg, Germany). Patients with an organ space infection upon laparotomy underwent an abdominal lavage with Ringer's lactate solution of at least 5 L, as described previously.[25,26]

The abdominal wall was closed with a continuous suture, with a suture/wound length ratio of 4:1, with a stitch length of approximately 1 cm, taking the fascia at approximately 1.5 cm distance from the midline incision.[27] The peritoneum was not closed separately. After the fascia was closed, the wound was rinsed with Ringer's lactate solution to clean out blood and cell debris. No subcutaneous sutures were used. The skin was closed with staples (Appose Single-Use Skin Stapler; Covidien, Mansfield, MA), and subsequently disinfected with polyvidone iodine in alcohol. Finally a sterile drape was applied to the wound and was left in place for at least 24 hours unless macroscopic bleeding soiled the drape. In patients with a history of cardiovascular disease, oxygen was supplied via a nasal tube to maintain an oxygen saturation of >95% postoperatively.[9] Patients requiring intensive care treatment had a tight postoperative glucose control and correction of hyperglycemic states by continuous or intermittent insulin administration.

Postoperatively wounds were assessed daily at the bedside by two observers blinded to the use of triclosan following a standard protocol included in the care pathway (see Supplementary data online). The definition of SSIs followed Centers for Disase

Control and Prevention criteria.[28] Wound infection was identified by the presence of erythema, induration, pain, and discharge of serous or contaminated fluid. Therefore, a bedside assessment was chosen as opposed to an assessment of wound pictures by remote investigators.[29] Wounds were assessed during the hospital stay and during follow-up 2 weeks postoperatively.

In patients with clinical signs for wound infections, bacterial cultures were obtained. In patients having secondary incisions (additional chemotherapy port for instance), only the primary, ie, abdominal incision was evaluated.

All data were entered via an electronic report form into our prospective clinical pathway data system (Clinical pathway module by GSD, ISH-Med, SAP Platform; SAP, Walldorf Germany[30,31]). On the basis of our previous results, we assumed an SSI reduction from 12% to 6%. Therefore, a sample size of 350 patients for each arm was calculated to achieve a power of $1 - b = 0.80$ for the one-sided χ^2 test at level $a = 0.025$ and a low drop-out rate of 5%.

Differences between groups were calculated by χ^2 or Fisher exact test for categorical variables, Mann-Whitney *U* test for continuously variables, using the SPSS (Version 14, Chicago, IL) software, and SAS Analytics (SAS Institute GmbH; Heidelberg, Germany). Data included all biographic and perioperative data as well as postoperative outcome. A multiple logistic regression analysis was performed entering the risk factors gender, American Society of Anesthesiologists classification, body mass index >30, malignant disease, the wound status, and antiseptic coating as variables. Data are given as absolute numbers, mean and SEM or as median (range) unless indicated otherwise.

RESULTS

Between September 2009 and September 2011, 1,497 consecutive patients admitted to our department were screened to undergo open abdominal exploration and surgery and closure of the incision in a standardized fashion (Fig).[27] A total of 1,042 of those patients gave written consent and were included in the trial.

Thirty-two patients subsequently refused surgery, and 43 patients had minimally invasive procedures or received nonsurgical therapies. Of the 967 patients undergoing open abdominal surgery and closure with a polydioxanone suture, 18 patients had a burst abdomen, and 71 patients had a planned revision within 30 days or an on demand re-laparotomy for organ space infections. Those patients were excluded from further analysis because a secondary contamination of the wound and subsequent wound infection might be unrelated to the use of triclosan impregnated sutures during the first procedure. Ten patients died postoperatively, and in 12 patients the abdomen was not closed during the initial procedure, leaving 856 patients for complete evaluation of their wound status.

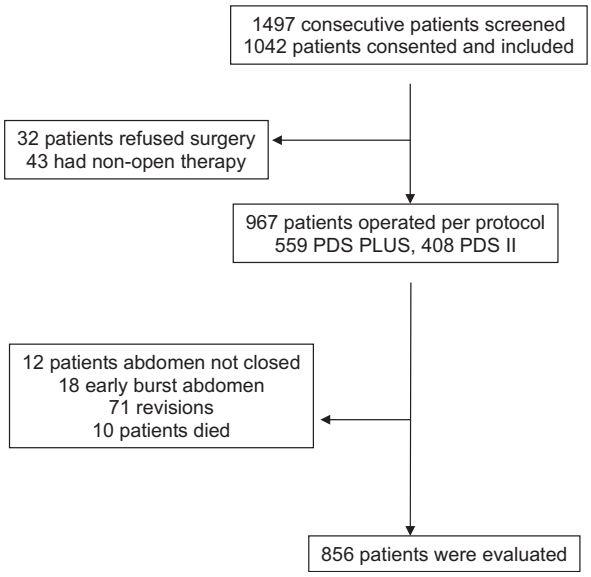

Fig. Flow chart of screened and treated patients of the NCT00998907 trial.

A total of 371 patients were randomized to PDS II and 485 patients to PDS II Plus. Sex, age, and BMI as well as the ASA classification was not different between the two groups. There were more clean wounds in the PDS II group and more clean-contaminated wounds in the PDS Plus groups (Table I), the difference, however, was not significant. Blood loss, duration of surgery, and duration of hospital stay were comparable between the two groups as was the duration of surgery (Table II). The rate of wound infection was 11.3% in the PDS II group and 6.4% in the PDS Plus group ($P < .05$).

On multivariate analysis, the use of a PDS Plus suture decreased the odds of developing a wound infection in abdominal surgery to 0.501 (95% confidence interval 0.3–0.9, $P < .05$). Patients who underwent colorectal resections (ie, clean contaminated or contaminated procedures) had a 3.3-fold greater odds of developing a wound infection compared with patients undergoing non-colorectal procedures. Patients with a body mass index of 30 kg/m^2 or more had a 1.68-fold risk of developing a wound infection (95% confidence interval 0.8-3.2, $P = .12$; Table III).

Table I. Demographic data of cohort

Parameter	*PDS II,* n = *371*	*PDS Plus,* n = *485*	P *value*
Sex, *n* (%)			.616
Male	224 (60.4)	301 (62.1)	
Female	147 (39.6)	184 (37.9)	
Age, years	63 ± 13	63 ± 13	.923
BMI, *n* (%)			.713
<18	7 (1.9)	14 (2.9)	
18–25	181 (48.8)	221 (45.6)	
26–30	129 (34.8)	174 (35.9)	
>30	54 (15.8)	76 (16.4)	
ASA, *n* (%)			.550
1	21 (7.3)	25 (5.5)	
2	164 (56.9)	249 (54.4)	
3	98 (34)	176 (38.4)	
4	5 (1.7)	8 (1.7)	
Inflammatory bowel disease, *n* (%)	7 (1.9)	14 (2.9)	.869
Diabetes mellitus, *n* (%)	35 (9.4)	49 (10.1)	.419
Blood transfusion, *n* (%)*	14 (3.9)	23 (4.8)	.369
Malignancy, *n* (%)	264 (71.4)	355 (73.2)	.550
Wound classification, *n* (%)			<.05
Clean	245 (66) {22; 8.9%}†	286 (59) {14; 4.8%}†	
Clean contaminated	97 (26.1) {16; 16.5%}†	162 (33.4) {14; 8.6%}†	
Contaminated	25 (6.7) {4; 16%}†	37 (7.6) {3; 8.1%}†	
Septic	4 (1.1) {0}†	0 (0) {0}†	

*Number of patients with perioperative blood transfusion.
†Brackets indicate the number of infections within each classification.
ASA, American Society of Anesthesiologists; *BMI*, body mass index.

Table II. Peri- and postoperative data of cohort

Parameter	*PDS II,* n = *371*	*PDS Plus,* n = *485*	P *value*
Blood loss, mL	366 ± 509	316 ± 485	.176
IHOS, days	15 ± 13 (2–134)	11 ± 18 (2–209)	.300
OR time, min	137 ± 68	138 ± 65	.860
Access, *n* (%)			.218
Median laparotomy	279 (75.2)	382 (78.8)	
Transverse laparotomy	92 (24.8)	103 (21.2)	
Type of surgery, *n* (%)			.883
Upper GI tract	41 (11.1) {2; 5%}*	59 (12.2) {3; 5%}*	
Hepatopancreatobiliary	173 (46.6) {14; 8%}*	210 (43.4) {9; 4%}*	
Small intestine	14 (3.8) {3; 21%}*	19 (3.9) {1; 5%}*	
Colorectal	100 (27.7) {19; 19%}*	143 (29.5) {17; 12%}*	
Vascular surgery	24 (6.5) {0}*	26 (5.4) {0}*	
Other	19 (5.1) {4; 21%}*	27 (5.4) {1; 4%}*	
Wound infection	42 (11.3)	31 (6.4)	<.05

*Brackets indicate the number of infections within each category.
GI, Gastrointestinal; *IHOS*, in hospital stay; *OR*, operating room.

The four classical signs for wound infection were recorded in all patients. In patients developing wound infections, swelling and pain were the first signs seen on the 2nd and 3rd postoperative days. Erythema and warmth were later signs of wound infections, following on the 7th and 10th day, postoperatively (Fig). The proportion of bacterial species found in infected wounds is shown in Table IV. No difference could be detected between the two groups ($P > .05$). Most patients developing SSI were treated conservatively (PDS II: 35/42 [83.3%]; PDS Plus: 22/31 [71.0%]); five patients in the PDS II group and eight patients in the PDS Plus group had major surgical wound revisions (PDS II: 5/42 [11.9%]; PDS Plus: 8/31 [25.8%]).

Table III. Regression analysis

Parameter	*No wound infection*	*Wound infection*	*Odds ratio (95% CI)*	P *value*
PDS Plus suture	454	31	0.501 (0.3–0.9)	**<.05**
Female sex	303	28	1.08 (0.6–1.9)	.78
BMI > 30	116	14	1.68 (0.8–3.2)	.12
ASA > 2	262	25	1.14 (0.6–1.9)	.63
Diabetes mellitus	76	9	1.21 (0.5–2.8)	.66
Wound status contaminated or septic	59	7	1.05 (0.4–2.6)	.71
Malignancy	563	56	1.1 (0.6–2.0)	.75
Colorectal procedure	207	36	3.3 (1.9–5.7)	**<.05**

ASA, American Society of Anesthesiologists; *BMI*, body mass index; *CI*, confidence interval.

Table IV. Proportion of bacterial scpecies found in infected wounds

	PDS II	*PDS Plus*
SSI	11.3% (42/371)	6.4% (31/485)
Bacterial species		
Staphylococci	23.1%	23.1%
Enterococci	23.1%	30.1%
Streptococci	5.1%	5.1%
Pseudomonas spp.	0	5.1%
Enterobacteriacae	5.1%	2.5%
Others	15.4%	23.1%

SSI, Surgical-site infection.

DISCUSSION

In this prospective patient-, surgeon-, and observer-blinded randomized trial, we found a decrease in the rate of SSIs in patients undergoing fascia closure after a laparotomy with a triclosan-impregnated polydioxanone suture of 43% compared with a fascia closure with an unimpregnated polydioxanone suture. SSIs are the second most frequent health care– associated complications, amounting to approximately 300,000 infections per year in the United States alone.[32] Depending on the type of surgery the incidence was reported to range between 0% and >25%[1-3] in patients with contaminated surgical sites. Clearly, comorbidities such as diabetes, obesity, malignancy, and cachexia[1,2] increase the risk for SSIs; however, they might not be correctable preoperatively in patients requiring immediate surgery. On the other hand, health care–associated risk factors like inadequate skin preparation and antibiotic prophylaxis,[4,5] surgical technique and long operating times,[33] as well as inadequate perioperative care are amenable to correction. Interestingly, several surveillance studies found compliance rates with current antibiotic prophylaxis guidelines for instance to be 35% or less.[34,35] Also, under study conditions, following stringent intraoperative hygiene protocols may not be greater than 65%[36] without previous and continuous education and training.

Reasons for that low compliance are not merely neglect but are often caused by a lack of standardization and training, personal fluctuation, time and resource constraints, as well as insufficient communication between care providers.[37] Those factors, together with the multi factorial etiology of SSIs and a lack of standardized methods for SSI surveillance,[28] might be some of the reasons for the failure of large scale programs to reduce SSIs.[38]

Additionally, those factors might complicate the design but also interpretation of clinical especially multicenter trials that try to translate a well proven biological effect of a singular intervention or molecules into clinical practice. Triclosan, for instance, a chlorinated phenolic molecule, was shown to have profound antibacterial activities against a number of gram-positive and gram-negative bacteria, with a 90% to 99.9% reduction in *Escherichia coli* and *Staphylococcus aureus* inoculates, respectively.[39] In vivo it reduces bacterial adhesion to braided sutures, thus decreasing microbial viability in surgical wounds.[40] The antibacterial activity of triclosan-impregnated sutures was maintained until the sutures dissolved.[39]

Subsequent clinical studies were able to demonstrate the beneficial effect of triclosan on SSIs in randomized[13,14] as well as large-scale, well-controlled retrospective studies.[18,19] Other trials, however, failed to demonstrate an effect of triclosan impregnated sutures on SSIs probably because of underpowering of the trials in patients at low risk for SSIs.[15,41] Other studies lacked an adequate control of confounding factors for clinical signs of SSIs like limb ischemia[42,43] or they failed to standardize perioperative management and wound surveillance.[16]

One of the limitations of our previous two trials was the lack of randomization, which was corrected in the present study. For logistic reasons and to facilitate a high patient recruitment rate, randomization was facilitated in a group fashion rather than a randomization of each individual, assigning

groups of 50 to 100 consecutive patients either to control or the triclosan treatment group. This allowed for a very high recruitment rate, large study groups with little variation in perioperative management and surgical technique, and constancy in the staff involved in patient care. Also, the computer-based clinical pathway system applied as a strategic management tool provided a high grade of documentation and standardization.

That high recruitment rate of more than 850 patients within 1 year in a single institution guaranteed not only a high constancy of treatment but allowed a rapid clinical assessment of new surgical and medical products, which sharply contrasts to conventional recruitment rates of less than 50 patients/year and study recruitment times of several years[29] for similar trials conducted at other high-volume centers.[11,43] In addition to those advantages, the current clinical pathway facilitated study design is significantly less expensive than conventional multicenter RCT.

The high documentation density and quality of the surgical site in this study allows for the first time to delineate a time course of SSIs after laparotomy. Wound secretion and pain were early signs occurring as early as 2 to 3 days postoperatively, followed by redness and heat later in the course of SSIs. To develop early intervention strategies for abdominal SSIs, that finding would need to be confirmed in further studies.

In summary, this clinical pathway facilitated trial confirmed previous studies of our group that triclosan impregnation of a 2-0 polidioxanone closing suture decreases wound infections in patients having a laparotomy for general and abdominal vascular procedures.

Furthermore, the use ofclinical pathways and altering a single parameter within this pathway in a blinded randomized fashion might be a novel technique for clinical studies. Those studies can rapidly assess novel medical products at a fraction of the cost of conventional multicenter clinical trials.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at http://dx.doi.org/10.1016/j.surg.2013.04.011.

REFERENCES

1. Chong T, Sawyer R. Update on the epidemiology and prevention of surgical site infections. Curr Infect Dis Rep 2002;4:484-90.
2. Fry DE. A systems approach to the prevention of surgical infections. Surg Clin N Am 2009;89:521-37.
3. Department of Health and Human Services. Action Plan to Prevent Healthcare-Associated Infections. Available from: http://www.hhs.gov/ophs/initiatives/hai/infection.html.
4. Bellows CF, Mills KT, Kelly TN, Gagliardi G. Combination of oral non-absorbable and intravenous antibiotics versus intravenous antibiotics alone in the prevention of surgical site infections after colorectal surgery: a meta-analysis of randomized controlled trials. Tech Coloproctol 2011;15:385-95.
5. Lee I, Agarwal RK, Lee BY, Fishman NO, Umscheid CA. Systematic review and cost analysis comparing use of chlorhexidine with use of iodine for preoperative skin antisepsis to prevent surgical site infection. Infect Control Hosp Epidemiol 2010;31:1219-29.
6. Sajid MS, Shakir AJ, Khatri K, Baig MK. The role of perioperative warming in surgery: a systematic review. Sao Paulo Med J 2009;127:231-7.
7. Moola S, Lockwood C. Effectiveness of strategies for the management and/or prevention of hypothermia within the adult perioperative environment. Int J Evid Based Healthc 2011;9:337-45.
8. Brar MS, Brar SS, Dixon E. Perioperative supplemental oxygen in colorectal patients: a meta-analysis. J Surg Res 2011;166:227-35.
9. Togioka B, Galvagno S, Sumida S, Murphy J, Ouanes JP, Wu C. The role of perioperative high inspired oxygen therapy in reducing surgical site infection: a meta-analysis. Anesth Analg 2012;114:334-42.
10. Campbell DA Jr, Henderson WG, Englesbe MJ, Hall BL, O'Reilly M, Bratzler D, et al. Surgical site infection prevention: the importance of operative duration and blood transfusion—results of the first American College of Surgeons-National Surgical Quality Improvement Program Best Practices Initiative. J Am Coll Surg 2008;207:810-20.
11. Seiler CM, Bruckner T, Diener MK, Papyan A, Golcher H, Seidlmayer C, et al. Interrupted or continuous slowly absorbable sutures for closure of primary elective midline abdominal incisions: a multicenter randomized trial (INSECT: ISRCTN24023541). Ann Surg 2009;249:576-82.
12. Yazdankhah SP, Scheie AA, Høiby EA, Lunestad BT, Heir E, Fotland TØ, et al. Triclosan and antimicrobial resistance in bacteria: an overview. Microb Drug Resist 2006;12:83-90.
13. Rozzelle CJ, Leonardo J, Li V. Antimicrobial suture wound closure for cerebrospinal fluid shunt surgery: a prospective, double-blinded, randomized controlled trial. J Neurosurg Pediatr 2008;2:111-7.
14. Galal I, El-Hindawy K. Impact of using triclosan-antibacterial sutures on incidence of surgical site infection. Am J Surg 2011;202:133-8.
15. Williams N, Sweetland H, Goyal S, Ivins N, Leaper DJ. Randomized trial of antimicrobial-coated sutures to prevent surgical site infection after breast cancer surgery. Surg Infect (Larchmt) 2011;12:469-74.
16. Baracs J, Huszár O, Sajjadi SG, Horváth OP. Surgical site infections after abdominal closure in colorectal surgery using triclosan-coated absorbable suture (PDS Plus) vs. uncoated sutures (PDS II): a randomized multicenter study. Surg Infect (Larchmt) 2011;12:483-9.
17. Furnary AP. Clinical benefits of tight glycaemic control: focus on the perioperative setting. Best Pract Res Clin Anaesthesiol 2009;23:411-20.
18. Justinger C, Moussavian MR, Schlueter C, Kopp B, Kollmar O, Schilling MK. Antibacterial [corrected] coating of abdominal closure sutures and wound infection. Surgery 2009;145:330-4.
19. Justinger C, Schuld J, Sperling J, Kollmar O, Richter S, Schilling MK. Triclosan-coated sutures reduce wound

infections after hepatobiliary surgery—a prospective nonrandomized clinical pathway driven study. Langenbecks Arch Surg 2011;396:845-50.
20. Furnary AP, Wu Y. Eliminating the diabetic disadvantage: the Portland Diabetic Project. Semin Thorac Cardiovasc Surg 2006;18:302-8.
21. Bode LG, Kluytmans JA, Wertheim HF, Bogaers D, Vandenbroucke-Grauls CM, Roosendaal R, et al. Preventing surgical-site infections in nasal carriers of *Staphylococcus aureus*. N Engl J Med 2010;362:9-17.
22. Tanner J, Norrie P, Melen K. Preoperative hair removal to reduce surgical site infection. Cochrane Database Syst Rev 2011:CD004122.
23. Wacha H, Hoyme U, Isenmann R, Kujath P, Lebert C, Naber K, et al. Perioperative antibiotika-prophylaxe. Chemother J 2010;19:70-84.
24. Edwards JP, Ho AL, Tee MC, Dixon E, Ball CG. Wound protectors reduce surgical site infection: a meta-analysis of randomized controlled trials. Ann Surg 2012;256:53-9.
25. Richter S, Lindemann W, Kollmar O, Pistorius GA, Maurer CA, Schilling MK. One-stage sigmoid colon resection for perforated sigmoid diverticulitis (Hinchey stages III and IV). World J Surg 2006;30:1027-32.
26. Schilling MK, Maurer CA, Kollmar O, Büchler MW. Primary vs. secondary anastomosis after sigmoid colon resection for perforated diverticulitis (Hinchey Stage III and IV): a prospective outcome and cost analysis. Dis Colon Rectum 2001;44:699-703.
27. Bolli M, Schilling M. Incision and closure of the abdominal wall. Chirurg 2006;77:408-13.
28. Surgical site infection event. Available from: http://www.cdc.gov/nhsn/PDFs/pscManual/9pscSSIcurrent.pdf.
29. Heger U, Voss S, Knebel P, Doerr-Harim C, Neudecker J, Schuhmacher C, et al. Prevention of abdominal wound infection (PROUD trial, DRKS00000390): study protocol for a randomized controlled trial. Trials 2011;12:245.
30. Schilling MK, Richter S, Jacob P, Lindemann W. Clinical pathways—first results of a systematic IT-supported application at a surgical department of a university hospital. Dtsch Med Wochenschr 2006;131:962-7.
31. Graeber S, Richter S, Folz J, Pham PT, Jacob P, Schilling MK. Clinical pathways in general surgery. Development, implementation, and evaluation. Methods Inf Med 2007;46:574-9.
32. Anderson DJ, Kaye KS, Classen D, Arias KM, Podgorny K, Burstin H, et al. Strategies to prevent surgical site infections in acute care hospitals. Infect Control Hosp Epidemiol 2008;29(Suppl 1):S51-61.
33. Ata A, Lee J, Bestle SL, Desemone J, Stain SC. Postoperative hyperglycemia and surgical site infection in general surgery patients. Arch Surg 2010;145:858-64.
34. Tourmousoglou CE, Yiannakopoulou ECh, Kalapothaki V, Bramis J, St Papadopoulos J. Adherence to guidelines for antibiotic prophylaxis in general surgery: a critical appraisal. J Antimicrob Chemother 2008;61:214-8.
35. Al-Momany NH, Al-Bakri AG, Makahleh ZM, Wazaify MM. Adherence to international antimicrobial prophylaxis guidelines in cardiac surgery: a Jordanian study demonstrates need for quality improvement. J Manag Care Pharm 2009;15:262-71.
36. Beldi G, Bisch-Knaden S, Banz V, Mühlemann K, Candinas D. Impact of intraoperative behavior on surgical site infections. Am J Surg 2009;198:157-62.
37. Hawn MT, Vick CC, Richman J, Holman W, Deierhoi RJ, Graham LA, et al. Surgical site infection prevention: time to move beyond the surgical care improvement program. Ann Surg 2011;254:494-9.
38. Ming X, Rothenburger S, Nichols MM. In vivo and in vitro antibacterial efficacy of PDS plus (polidioxanone with triclosan) suture. Surg Infect (Larchmt) 2008 Aug;9:451-7.
39. Edmiston CE, Seabrook GR, Goheen MP, Krepel CJ, Johnson CP, Lewis BD, et al. Bacterial adherence to surgical sutures: can antibacterial-coated sutures reduce the risk of microbial contamination? J Am Coll Surg 2006;203:481-9.
40. Stadler S, Fleck T. Triclosan-coated sutures for the reduction of sternal wound infections? A retrospective observational analysis. Interact Cardiovasc Thorac Surg 2011;13:296-9.
41. Turtiainen J, Saimanen EI, Mäkinen KT, Nykänen AI, Venermo MA, Uurto IT, et al. Effect of triclosan-coated sutures on the incidence of surgical wound infection after lower limb revascularization surgery:a randomized controlled trial. World J Surg 2012;36:2528-34.
42. Seim BE, Tønnessen T, Woldbaek PR. Triclosan-coated sutures do not reduce leg wound infections after coronary artery bypass grafting. Interact Cardiovasc Thorac Surg, in press.
43. Fischer L, Knaebel HP, Golcher H, Bruckner T, Diener MK, Bachmann J, et al. To whom do the results of the multicenter, randomized, controlled INSECT trial (ISRCTN 24023541) apply? Assessment of external validity. BMC Surg 2012;12:2.