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Review Article

A review of current strategies to reduce intraoperative bacterial contamination of surgical wounds

Übersicht über gegenwärtige Strategien zur Reduktion der intraoperativen bakteriellen Kontamination von Op-Wunden

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Abstract

Surgical site infections are a mean topic in cardiac surgery, leading to a prolonged hospitalization, and substantially increased morbidity and mortality. One source of pathogens is the endogenous flora of the patient's skin, which can contaminate the surgical site. A number of preoperative skin care strategies are performed to reduce bacterial contamination like preoperative antiseptic showering, hair removal, antisepsis of the skin, adhesive barrier drapes, and antimicrobial prophylaxis. Furthermore we can also support the natural host defense by optimal intra-operative management of oxygen supply, normoglycemia, and temperature. Nevertheless we still have a number of patients, who develop a surgical site infection. Therefore new skin care strategies are introduced to reduce the contamination by the endogenous skin flora. We present the use of a new microbial sealant, IntegoSeal®, which was evaluated in patients undergoing cardiac surgery. The preliminary results of this investigation showed a trend in surgical site infection reduction by the use of this new microbial sealant.

Keywords: skin bacteria, antibiotic prophylaxis, antibiotic resistance, microbial sealant, surgical site infections

Zusammenfassung

Die Prävention postoperativer Wundinfektionen ist ein wichtiges Anliegen in der Herzchirurgie, weil diese mit erhöhter Morbidität, Mortalität und verlängerter Krankenhausverweildauer verbunden sind. Eine gesicherte Infektionsquelle ist die residente Hautflora des Patienten, die die Op-Wunde kontaminieren kann. Deshalb wird eine Reihe präoperativer Maßnahmen zur Reduktion der Hautflora durchgeführt wie antiseptisches Ganzkörperduschen, Haarentfernung, Hautantiseptik, Inzisionsfolien und Antibiotikaprophylaxe. Weiterhin kann die natürliche Wirtsabwehr durch optimale intraoperative Sauerstoffversorgung, adäquate Einstellung des Blutglukosespiegels und Gewährleistung der Normothermie für die Op-Dauer unterstützt werden. Weil trotzdem postoperative Wundinfektionen auftreten können, werden neue Strategien zur Vermeidung der intraoperativen Kontamination durch die Hautflora benötigt. Hierfür wurde als neue aussichtsreiche Möglichkeit IntegoSeal® entwickelt und die Effektivität dieser Versiegelungsmethode im Bereich der Hautdurchtrennung bei Patienten mit herzchirurgischen Operationen untersucht. Die vorläufigen Ergebnisse zeigen den Trend einer Reduktion der Rate postoperativer Wundinfektionen.

Schlüsselwörter: Hautbakterien, antibiotische Prophylaxe, Antibiotikaresistenz, mikrobielle Abdichtung, postoperative Wundinfektion

Introduction

Surgical site infections (SSIs) are serious complications among cardiac surgery. The prevalence of SSIs has been reported to range from 1.3 to 12.8% [1], [2], [3], [4], leading to a prolonged hospitalization, and substantially increased morbidity and mortality. Generally during a cardiac surgical procedure, the skin needs to be incised and the exposed tissues are at risk for contamination by the endogenous skin flora; usually aerobic gram-positive microbes [5].
Due to the increase complexity of surgical procedures which are performed and the increase number of patients with a serious co-morbidity, the risk of SSIs increases. Therefore, new strategies within daily cardiac surgery practices need to be evaluated.

Pathogenesis of surgical site infection

For most SSIs, the source of pathogens is the endogenous flora of the patient's skin [6], [7]. As long as the skin is intact, it resist microbial invasion due to relative dryness, cell mediated immunity and antibody production from T-lymphocytes [8]. Therefore, microbial contamination of the surgical site is a necessary precursor to develop SSIs, however not every contaminated wound will finally result in an infected wound. The risk of SSIs conceptualized according to the following relationship. On the one hand side there is the amount of inoculated and virulence of bacteria. On the other hand side we have the natural host defense due to the innate immune system to eliminate bacteria. A surgical site infection will normally occur when the contamination of pathogens overcome the host defense system. Quantitatively, 10^5 microorganisms per gram of tissue will be needed to increase markedly the probability to develop a SSIs [9].

Reduction of bacterial contamination of the surgical site

Preoperative management

A number of preoperative skin care strategies will be reviewed to reduce the risk for contamination by endogenous skin flora at the surgical site.

Preoperative antiseptic showering

A preoperative antiseptic shower or bath decreases skin microbial colony counts. Garibaldi performed a study with more than 700 patients, using different preoperative antiseptic showers [10]. Chlorhexidine reduces the bacterial colony counts 9.0-fold, while povidine-iodine or tricarban-medicated soap reduced colony counts at the skin only 1.3- and 1.9-fold, respectively. These positive results of reducing the skin's microbial colony counts due to preoperative showering have no significant influence on incidence of SSIs rates [11], [12], [13].

Hair removal

Body hair has been though to be a potential carrier of pathogens and therefore it should be removed from the surgical site. There are different methods to remove hair such as shaving with a razor, using an electrical clipper; or applying a depilatory cream. A number of clinical trials compared various combinations of these preparatory techniques. In general, depilatory cream usage was most favorable to reduce the risk of SSI [14], [15].
Although the use of depilatories has been associated with a lower risk of SSI than shaving or clipping, sometimes patients suffer from hypersensitivity reactions [16]. Seropian showed in the same study that SSI rates were as high as 5.6% in patients shaved by a razor compared with the use of depilatory creams 0.6%. The reason for this increased SSI risk could be due to the produced microscopic cuts, that later could serve as a foci for bacterial multiplication [17].
Another important issue is the timing to perform shaving. During an emergency procedure, the razor, ideally by using an electrical clipper, will be performed immediately before surgery will be started. During an elective procedure, however clipping hair immediately before an operation has been associated with a lower risk for SSIs, rather than clipping the night before the operation, respectively 1.8% versus 4.0% [18].
Other studies however suggested that independent to the shaving method, hair removal was associated with increased SSIs compared to no hair removal [19]. Therefore it is still difficult to make final comments on the topic hair removal.

Antisepsis of the patient skin

Antisepsis of the skin is an important issue to reduce the concentrations of bacteria at the operative site. Lilly et al. [20] showed a progressive reduction due to the "two-phase" antisepsis as an appropriate method for achieving a higher degree of antisepsis of operation sites. Due to repeated antisepsis of the skin a further mean reduction of 90% or more in the yield of bacteria could be shown. This means that by the use of antiseptic preparations one can reduce in yield of resident flora to a low equilibrium level, however complete decontamination will never occur.
Kampf et al. [21] showed that the best antimicrobial efficacy could be achieved with alcohol based antiseptic solutions. Ethanol at higher concentrations, 70%, showed to be the most effective treatment against naked viruses, whereas propan-1-ol was more effective against the resident bacterial skin flora. The combination of alcohols is suggested to have a synergistic effect. The promotion of alcohol-based antisepsis, containing emollients, is also a strategy to reduce skin damage and irritation.

However, the golden rule for the use of antiseptic solutions is that an antiseptic solution can not be effective unless it will completely dries.

Adhesive barrier drapes

Antiseptic solutions can also wash off during the surgical procedure allowing potential bacterial re-growth. Therefore the use of plastic adhesive drapes were introduced to prevent the direct exposure with the skin in which remaining or regenerating skin bacteria could be carried into the surgical wound. Another option would be the use of adhesive drapes impregnated with iodophor to allow a continuously application of iodine, to reduce potential bacterial re-growth. As some of the patients suffer from iodine-allergy, the used of these drapes are, however sometimes contra-indicated.
In a bacteriological study of Fairclough et al. [22], were two groups of patients with (n=122) or without (n=107) iodophor impregnated plastic adhesive drapes compared. The results of this study showed a 10- fold decrease of SSIs in the group using this iodophor impregnated plastic adhesive drapes. Yoshimura et al. [23] showed in a similar study by 296 patients, that there was evidence for using plastic adhesive drapes during surgery for preventing superficial surgical site infections. Wound infection was significantly less likely with the use of iodophor adhesive drapes (3.1%) than for surgery without iodophor drapes (12.1%) ($p>0.02$). However, the relation ship between using iodophor impregnated plastic adhesive drapes or not and the risk for SSI has not yet been adequately studied [24], [25].

Antibiotic prophylaxis

The risk of developing a postoperative infection depends on the bacterial count in the wound by the end of the operation [24]. Recent treatment with antibiotics may change the commensal flora which allows colonization with more antibiotic-resistant bacteria [26]. In these circumstances it maid be wise to delay elective surgical procedures, if the patient is on or has just finished antibiotic treatment.
With antibiotic prophylaxis, the threshold for developing infection was decreased, but the risk still depends on the degree of bacterial wound contamination [27].
Prophylactic intravenous antibiotics should be routinely administered to patients undergoing cardiac surgery. In other surgical specialties, there seems to be little debate regarding prophylactic antibiotic duration. However, in cardiac surgery there are several factors contribute to the divergence of practice patterns:

- optimum duration has not been adequately explored with identical antibiotics
- SSIs have been low during the years
- there has been only a vaguely perceived downside to aggressive, prolonged prophylaxis.

Today there is a mounting evidence of important disadvantages to prolonged prophylaxis. Emerging antibiotic resistance which seems to be an important issue is 1) real, 2) clinically important, and 3) directly linked to the duration of prophylactic antibiotic administration.
Harbarth et al. [28] showed in a trial of 2641 patients undergoing coronary bypass surgery, that antibiotic prophylaxis in patients receiving more than 48 hours have an increased risk of antimicrobial resistance.
For the issue single versus multiple dose antibiotic prophylaxis there is not yet a final statement possible due to the lack of inconclusive data. DiPiro et al. [29] reviewed the literature about single-dose antibiotic in surgery and concluded “the value of single-dose regimens during open heart surgery has not yet been established”.
The first few hours following bacterial contamination constitute a decisive period during which infection may be established [30]. The effects of antibiotic administration are especially important during this period of time. Antibiotics are effective when given within 3 hours of bacterial inoculation but are ineffective when given more than 3 hours after inoculation [31], [32].

Intraoperative management

Another strategy to reduce SSIs is to improve the general intraoperative condition of the patient, supporting the natural host defense to eliminate bacteria.

Optimal temperature

General anesthesia profoundly impairs thermoregulatory control and nearly all unwarmed surgical patients become hypothermic. This results in a shift from core-to-peripheral distribution of the core temperature [33]. Even mild hypothermia can lead to severe complications including SSIs. Hypothermia may facilitate perioperative wound infection in two ways. First, sufficient intraoperatively hypothermia triggers thermoregulatory vasoconstriction [34] and the risk of wound infection correlates with subcutaneous oxygen tension [35]. Secondary, mild core hypothermia directly impairs immune function including T-cell-mediated antibody production [36] and “non-specific” oxidative bacterial killing by neutrophils [37].
Kurz et al. [38] showed in randomized study that the surgical site infection rate was tripled if the core temperature was decreased 1.9°C from 36.5°C (n=104) to 34.5°C (n=96). The SSI rate in both groups was respectively 5.8% versus 18.8% ($p<0.009$). Another issue in this study was the fact, that patients were oxygenated three hours longer compared to the patients which were normothermic monitored. During cardiopulmonary bypass, this problem is minimal, however after surgery the core temperature can drop, resulting in a prolonged oxygenation. In off-pump, cardiac surgery, absence of cardiopulmonary bypass use, this issue is a much more prominent.

Optimal glycemic control

Diabetic patients have a two-to-three times increased risk for SSI compared with non-diabetic patients after cardiac surgery [39]. Furnary et al. [40] demonstrated a significant reduction in deep sternal wound infections when perioperative insulin management was switched from subcutaneous to continuous insulin infusion. In this prospective study 2467 consecutive diabetic patients were included undergoing cardiac surgery. There were no differences in both groups according patient characteristics. The deep sternal SSI could be significantly decreased ($p<0.01$) compared to the patients which received insulin intermittent subcutaneously. This can be explained by the deleterious effect of a hyperglycemia on macrophage or neutrophil function [41].

Doenst et al. [42] performed a study on in total 6280 patient, diabetic (n=1579) and non-diabetic (n=4701), who underwent cardiac surgery and insulin was given if the glucose levels exceeded 15 mmol/L. There results showed that closely control of the intraoperatively glycemia not only decrease the operative mortality in diabetic but also in non-diabetic patients.

Hyperglycemia was an independent predictor of mortality in patients with diabetics (Odds ratio 1.20 ($p=0.0005$)) and all adverse events, including SSIs (Odds ratio 1.04 ($p=0.0378$)). A similar results was achieved in non-diabetic patients (Odds ratio 1.20 ($p=0.0005$)) for the operative mortality and all adverse events, including SSIs (Odds ratio 1.04 ($p=0.0378$)).

Based on these studies it seems that hyperglycemia *per se* increases the risk for SSIs and wound infection can not be explained by the changes of the micro-circulation of patients suffering from diabetic for many years [43].

Optimal oxygenation

The most important immune defense against surgical pathogens are neutrophils, mediated by oxidative killing and dependent on the production of bactericidal superoxide radicals from molecular oxygen [44]. The rate of reaction, catalyzed by NADPH-linked oxygenase, is dependent on the partial pressure of tissue oxygen [45]. The surgical incision will disrupt the local vascular supply, which cause hypoxia of a wound compared with normal tissue [46]. Therefore neutrophils activity depends on the partial pressure of oxygen [35]. Based on this background information, Grief et al. [45] performed a randomized double-blind study in patients undergoing colorectal resection. Supplemental 30 or 80% inspired oxygen showed a significant decrease of surgical-wound infections ($p=0.01$), respectively 13/250 patients or 5.2% and 28/250 patients or 11.2%.

Belda et al. [47] showed similar results by performing supplementary oxygen in a randomized study on patients undergoing colon surgery. Surgical wound infections occurred in 24.4% of patients receiving 30% oxygen, whether 14.9% of those receiving 80% oxygen. There was a statistical significant decrease found in this study ($p=0.04$).

Hypoxia does not only induce peripheral vasoconstriction, which decrease the blood supply into the wound but also provokes pulmonary expression of inflammatory cytokines. Furthermore oxygen partial pressure in wounds regulates angiogenesis.

Velazquez [48] demonstrated in the mice model the impact of angiogenesis and vasculogenesis in the wound healing in ischemic and diabetic. The normal blood supply improved wound healing due to the optimal delivery of oxygen, nutrients, growth factors and progenitor cells and removing the waste products.

In summary

Although we have a number of preoperative skin care strategies (e.g. preoperative antiseptic showering, hair removal, antisepsis of the patient skin, adhesive barrier drapes and antimicrobial prophylaxis) to reduce the risk for contamination by endogenous skin flora at the surgical site and optimized protocols as general intraoperatively condition (e.g. optimal core temperature, optimal glycemia, and optimal oxygen supply) to support the natural host defense to eliminate bacteria new tools will be needed to neutralize patient's increased risk factors for wound infections.

New preoperative skin care strategies - pilot study with InteguSeal®

Introduction

To decrease the contamination by the endogenous skin flora, a microbial sealant, InteguSeal®, (Kimberly Clark Health Care, Atlanta, Georgia, USA) was recently introduced. The advantage of InteguSeal®, a n-butyl cyanoacrylate, intends to be applied on the skin over the commonly used surgical skin preparation. Upon contact with the pre-operative antiseptic treated skin, InteguSeal® bonds to the skin and immobilize the bacteria. Naturally and gradually InteguSeal® will wears off the skin, as skin exfoliates will started after three to seven days. We started a pilot study to see the effect of this microbial sealant in patient undergoing cardiac surgery.

Method

The total number of patients available, starting from February 2007 till July 2007, for this analysis were 350 patients, namely 60 with InteguSeal® and 290 patients without InteguSeal®. Data were grouped into patient characteristics, operative data, postoperative data and complications. The risk scoring system of Fowler et al. [49] was using to identify the preoperative and combined infection risk scores for major infection in both groups.

Statistical analysis

Data were analyzed using SPSS software (version 13.0; SPSS, Inc., Chicago, IL). Categorical variables were analyzed using Chi-square. Continuous variables were analyzed with Student's *t* test. *P*-value of less than .05 was considered to be significant on two-tailed testing.

Results

The preoperative patient's characteristics (risk factors) of both groups were comparable in both groups in all variables, except the following: The patients treated with IntegeuSeal® showed a highly significant rate of lower ejection fraction (p=0.002), congestive heart failure (p=0.001) and acute myocardial infarction (p=0.008) compared with the control group.
The group of patients treated with IntegeuSeal® showed a highly significant number of patients undergoing concomitant procedures (p=0.001), emergent surgery (p=0.001), whether the control group showed a significant higher rate of patients with cardiopulmonary bypass time between 100-200 minutes (0.001), increase number of distal anastomoses (p=0.04) and elective operated (p=0.003).
The clinical endpoint showed that in the group treated with IntegeuSeal® one patient suffered from surgical site infection (1.7%), whether the control group showed eleven patients with a surgical site infection (3.8%), which was not statistically significant (p=0.41). However the risk scoring system of Fowler showed a statistical significant difference between the risk factors of the IntegeuSeal® group and the control group. The predicted surgical site infection due to the pre-operative risk factors was 3.1% (score: 9.7±3.9%) versus 2.3% (score: 7.4±3.0%) (p<0.001). The predicted surgical site infection based on the intra-operative risk factors was 2.3% (score: 7.8±3.3%) versus 1.9% (score: 6.2±3.1%) (p<0.001). Two of the eight patients suffering from SSI in the control group died because of sepsis.

Conclusion

There is no question about the fact that a surgical site infection is a major complication among cardiac surgery. There is no golden regime to exclude SSIs, however there are guidelines on preoperative skin care measures to reduce bacterial wound site contamination include preoperative antiseptic showering, hair removal, antisepsis of the patient's skin, adhesive barrier drapes, and antibiotic prophylaxis. The natural host defense to eliminate bacteria of the patients needs to be optimal to support the patient's intraoperatively condition include core temperature, glycemia, and oxygen supply .
Nevertheless we still have SSIs and therefore new strategies to decrease the contamination by the endogenous skin flora need to be evaluated. We started the use of a microbial sealant, called IntegeuSeal®, to evaluate the additional impact of this new tool on SSIs. First clinical results were promising, although there were no statistical significance seen compared with the control group.

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