INFECTIONS IN SHOULDER AND ELBOW SURGERY – INCIDENCE AND PREDISPOSITION
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INTRODUCTION
The incidence of postoperative infections in shoulder surgery is subject to the operative procedure. For anatomical shoulder prostheses an infection rate of 1.1% was reported (Gonzalez et al. 2011) whereas in reverse shoulder arthroplasty rates were observed at 3.8% (Zumstein et al. 2011). In rotator cuff repair rates between 0.4–1.9% were reported. The incidence in elbow arthroplasty is similar to shoulder arthroplasty with 3.3% (Voloshin et al. 2011) although earlier studies reported a much higher rate of elbow infections of up to 9% (Gschwend et al. 1996).

Aim, method
In this report, we aimed to expose the incidence and predisposition for infections in
shoulder and elbow surgery and strategies to prevent surgical site infections by the review of relevant literature on these topics.

Results
The cost of a postoperative infection is of socioeconomic relevance. If an infection occurs, an average of 9.7 additional hospital days stresses the patient and the health care system (Reichman and Greenberg 2009). The additional annual costs for the treatment of all postsurgical infections were calculated to be 1.4 billion euros only for England (Plowman 2000). A review from the United States reported that the costs of an infected patient add up to 115% of the costs of a non-infected patient (Reichman and Greenberg 2009). Strategies of prevention are of great importance in daily surgical routine. These areas include preoperative skin cleaning and shaving, the operative room environment, preoperative disinfection, the use of incision drapes, use of antibiotics, the surgical approach, drains, body temperature control, adequate oxygen and glucose levels, reduction of blood transfusions and the smoking behavior of the patient (Reichman and Greenberg, 2009).

Whether a preoperative bath or shower with or without antiseptics is protective for infections has not been demonstrated yet (Webster and Osborne 2012). Much debate has been addressed to the preoperative skin shave. In a Cochrane review by Tanner et al. (2011) clippers were reported to be superior compared to razors and that shaving and depilatory creams show similar results. It has been further demonstrated that shaving should be restricted only to those cases where it is necessary for the surgical access and it should be performed directly before the incision (Alexander et al. 2011). The operative room environment also is of great importance to reduce infections. HEPA filters are reported to provide the best effect. Laminar airflow systems may help, but their effect is concluded to be only minimal (Brandt et al. 2008). However, the most important rule affects the operative room team, reducing unnecessary conversations and movements are still reported as a very effective method of precaution and prevention of infections (Alexander et al. 2011). In a review of 33 years of register data patients with young age and male gender were observed to be at greater risk for periprosthetic infections after total shoulder arthroplasty (Singh et al. 2012). This might be linked to the observation that male patients are at a 2.5 greater risk for obtaining positive cultures for Propionibacterium acnes (P. acnes) in first time shoulder surgery (Hudek et al. 2014). P. acnes is a gram-negative bacterium, which has been associated multiply with, orthopedic and implant associated infections (Hudek et al. 2014). It resides deep in the pilosebaceous unit of the skin and disinfection is known to insufficiently eradicate P. acnes preoperatively (Lange-Asschenfeldt et al. 2011). Therefore, it can be displaced into deeper tissue layers during surgery leading to a typical „low-grade“ infection. These infections are evolving over a much longer period compared to acute infections provoked by germs with greater pathogenicity. Because low-grade infections do not necessarily elevate c-reactive proteins or leukocytes it is often difficult to detect them. Therefore, aseptic loosening might be in fact an infection with P. acnes. The germ can reside intracellular in humans for many years hiding within macrophages (Fischer et al. 2013). The observation of a higher incidence of shoulder infections in young males (Singh et al. 2012) and the simultaneous observation of a high P. acnes burden linked to the antero-lateral approach (Hudek et al. 2014) should alert the orthopedic surgeon when planning operative procedures. The most pilosebaceous units are situated around the acromion showing much greater P. acnes burden when compared to the knee or the hip region (Patel et al. 2009). The deltopectoral approach seems to be 2-times safer than
the antero-lateral approach with regard to P. acnes detection (Hudek et al. 2014). Interestingly, patients who report “loss of hair” are reportedly at lesser risk for obtaining P. acnes positive cultures form intraoperative samples when compared to those who report no loss of hair (Hudek et al. 2016). Another important predisposition for surgical site infections is obesity (Edmiston et al. 2004). Pharmacokinetic analysis suggests that dosing strategies may fail to provide adequate perioperative prophylaxis if the patient is obese. Tissue levels of Cefazolin at wound closure were reported to be much less when compared to a control with normal BMI. Patients with a mean BMI of 47 the antibiotics concentration at the surgical site was only 48% and just 10% in those with a BMI of 69 (Edmiston et al. 2004) compared to normal sized patients. Therefore, adequate dosing of antibiotics is mandatory in shoulder and elbow surgery. For example, 2 grams of Cefazolin are recommended in patients weighing between 80–160 kg while 1 gram is sufficient in those ≤ 80 kg (Alexander et al. 2011). The timing of preoperative antibiotics is also of great importance. One to thirty minutes before incision is recommended as the optimal time window (Bowater et al. 2009). However, a recent analysis calculated on the basis of over 7000 surgical procedures revealed that the optimal time point to apply prophylactic antibiotics is 4 minutes before the incision (Koch et al. 2013). However, the time point has to be modified for those antibiotics with slower tissue penetration properties. For example, Vancomycin has to be applied 1 hour before the incision (Alexander et al. 2011). In cases of time consuming surgical procedures the dosing interval has to be adapted (Alexander et al. 2011). The body temperature of the patient is also associated to the infection incidence. Normothermia or even hyperthermia is beneficial. In contrast, hypothermia will provoke vasoconstriction. The reduced blood flow in the subcutaneous area will reduce O2 tension and thereby increase the infection risk (Dharan and Pittet 2002). A relative infection risk of 6.3 has been linked to hypothermia when compared to Normothermia (Flores-Maldonado et al. 2001). Infection is also inversely related to tissue oxygen in a time dependent fashion. Neutrophils will lose their function and potential to eradicate bacteria when the O2 tissue level is < 30 mmHG (Hopf and Holm 2008). Therefore, patients with lesser O2 tissue levels are at greater risk for postsurgical infections, which is even more a problem for the obese. Therefore, postoperative O2 therapy reduces the infection risk and should be applied particularly in obese patients or those with decreased respiratory function (Qadan et al. 2009). Diabetics are also at greater infection risk. Their blood glucose levels should therefore be targeted preoperatively between 120–160 mg/dl for at least 3 days before surgery with the maximal target of reportedly 180 mg/dl (Alexander et al. 2011). The rate of deep infections rises by factor 6 if glucose levels are above 250 mg/dl (Alexander et al. 2011). Another predisposition for infections is a blood transfusion. It should therefore be avoided if possible. For each unit red packed blood cells the risk for an infection is reportedly raised by 5% (Bochicchio et al. 2008). If more than 4 units were given, the odds ratio raises even to 6.4 (Edna and Bjerke-aset 1992). Another critical predisposition is smoking. It increases surgical wound infections via several well-established mechanisms including vasoconstriction, which is associated with decreased tissue pO2. Smoking is the only modifiable predisposition for post-surgical infections. The risk is almost doubled and even higher when the smoker is obese (Alexander et al. 2011). A recent study involving 489 patients for ambulatory surgery, smoking had an adjusted odds ratio for wound complications of 16.3 in smokers vs. non-smokers (Myles et al. 2002). The time interval for
smoking abstinence is discussed to be at least 4 weeks, however conclusive data are missing (Sorensen et al. 2003).

**Conclusions**
In summary, the incidence of infections in shoulder and elbow surgery is ranging between 1–4%. A predisposition is male gender and young age. Low-grade infections are of special importance because of the pathogenicity of *P. acnes* and its strategies to persist within humans. Therefore, surgeons should be cautious when planning an antero-lateral approach to the shoulder in males. In obese patients dosing of antibiotics and postoperative O2 supply should be considered. Smoking is the only modifiable risk factor for infections and the patient should be explained to quit smoking in any case.
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