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Clinical practice in prevention of fracture-related infection: An international survey among 1197 orthopaedic trauma surgeons

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ABSTRACT

Introduction: Open fractures are still a challenge in orthopaedic trauma surgery, and compared to closed fractures, the rate of complications including fracture-related infection (FRI) remains significantly higher. Although different guidelines on prevention of FRI have been published in past decades, the current recommendations vary significantly. The objectives of this international questionnaire were to evaluate clinical practice procedures for the prevention of FRI in open fractures and to evaluate adherence to available guidelines.

Methods: A 17-item questionnaire regarding prophylaxis against infection in fracture care was administered by SurveyMonkey® and was sent via blast e-mail to all users of AOTrauma (Davos, Switzerland).

Results: Overall, 1197 orthopaedic trauma surgeons answered the survey. Although cephalosporins were the most commonly prescribed agents for perioperative antibiotic prophylaxis (PAP) in open fractures, a total of 13 different antibiotics were mentioned in the survey. Furthermore, the duration of PAP was extremely variable with a tendency towards longer treatment periods with increasing open fracture severity. The majority of surgeons (71%) agreed that the optimal duration of PAP was not well defined in the literature. The use of local anti-infective agents varied significantly, although all options received additional votes with increasing injury severity. Some of the other surgical aspects addressed in this review were associated with debridement and irrigation. A delay of six hours from injury to the first debridement was acceptable to 47% of surgeons, but delays were tolerable. Normal saline was the solution used most often for wound irrigation in open fractures (89%), with low-pressure irrigation being applied most commonly (55%).

Conclusions: This international survey provided an overview of clinical practice in FRI prevention, particularly in open fracture cases. The treatment of these serious injuries remains heterogeneous. A major issue is the lack of consensus concerning type and duration of PAP. Furthermore, there seems to be no agreement on the indication for the use of local anti-infective agents. Overall, it is unknown what the repercussions are of this lack of internationally accepted guidelines on daily clinical practice, but it is clear that standardised treatment protocols are preferable in the current medical landscape.

Introduction

Open fractures are a major challenge in orthopaedic trauma surgery. Compared to closed fractures, they often require multiple surgeries to achieve definitive soft-tissue closure and have a higher risk of fracture-related infection (FRI) [1]. The risk increases with greater injury severity as classified by Gustilo and Anderson (GA) [2]. Although this risk is well established, many aspects in the management of open fractures, such as the choice of antibiotic agents, duration of perioperative antibiotic prophylaxis (PAP), timing of surgery, application of local antibiotics, choice of irrigation fluid, and pressure, are still under debate.

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Published reports indicate infection rates up to 25% are still common [24], and these are higher than those for many other surgically-treated disease entities. This underscores the importance of identifying an optimal management protocol and establishing guidelines in order to decrease the infection rate of these challenging injuries. A study demonstrating the lack of consensus within this field might improve the awareness of this issue raised by the surgical community and improve international collaboration to create evidence-based guidelines to which surgeons should adhere.

The objectives of this international questionnaire were therefore to evaluate the current international clinical practice in orthopaedic trauma surgery with respect to prevention of FRI in open fractures and to determine whether surgeons adhere to the currently available evidence-based guidelines.

Materials and methods

Questionnaire development

A survey was designed and drafted by the authors, consisting of orthopaedic trauma surgeons and basic science researchers, all with clinical and/or scientific expertise in the field of FRI. Survey development followed the recommendations established by Burns et al. [3]. To allow specific answers to the study objectives, the questions were designed to be unambiguous. Two types of multiple-choice questions were used. The first included statements with an associated Likert Scale Ranking that ranged from strongly disagree to strongly agree to illustrate trends among respondents and for the other question type, the most appropriate answer(s) had to be chosen from a list [3]. Seventeen questions (supplementary material, online data) were generated using a modified Delphi process (via planned videoconferences or e-mail communications), wherein items were nominated and rated by the authors until a consensus was achieved [3,4].

The questionnaire was then evaluated by an independent international cohort of ten orthopaedic trauma surgeons, who were not involved in the development of the questionnaire. They checked reproducibility, redundancy, wording, and understanding and provided written feedback after the review. These respondents agreed on the appropriateness of each question and interpreted each in a consistent manner.

Questionnaire distribution

The questionnaire was created using SurveyMonkey® (www.surveymonkey.com, Palo Alto, California, USA) and was sent via blast e-mail to all AOTrauma registered members worldwide. AOTrauma is an international community of trauma and orthopaedic surgeons, musculoskeletal researchers, and operating room personnel dedicated to delivering knowledge, experience, and evidence to improve patient care and outcomes in the field of musculoskeletal trauma. The questionnaire was voluntary, and the link could only be opened once by a single IP address. The responses were anonymous and the questionnaire's availability was terminated four weeks after distribution.

Statistical analysis

Descriptive statistical analysis was performed for all data. Variables were reported as counts and percentages. The response rate was defined as the number of individuals who completed the survey in relation to those who verifiably received and opened the e-mail invitation.

Results

In total, 88,807 e-mail addresses were available in the AOTrauma user registry. Of the 26,597 recipients who opened the e-mail, 3506 clicked on the link to open the questionnaire. From this group, 1197 surgeons completed the questionnaire (4.5% of all opened e-mails). If not otherwise mentioned, all 1197 respondents answered the questions.

Demographics

The orthopaedic trauma surgeons that responded to our survey came from 112 different countries. The top 20 participating countries are shown in supplementary Table 1 (online data). Working experience was evenly distributed among respondents, (supplementary table 2, online data). Most participants (50%, n = 593) worked in a major trauma centre and/or University hospital (supplementary table 3, online data).

Antibiotic agents used for systemic prophylaxis

For closed fractures, the majority of the respondents reported using cephalosporins such as cefazolin (55%, n = 661), cefuroxime (23%, n = 283), and ceftriaxone (12%, n = 139) (Fig. 1). Overall, 13 different antibiotics were mentioned as possible candidates for PAP (Fig. 1 and supplementary table 4, online data). A small number of surgeons (11%, n = 135) reported that they did not use any form of PAP for treatment of closed fractures. Cephalosporins were also predominant in open fractures, although compared to closed fractures multiple other antibiotics were also frequently mentioned. Additional antibiotics, such as gentamicin, metronidazole, and vancomycin, were administered more frequently as the severity of the open wound increased (Table 1). Less than 1% of respondents reported they did not use systemic antibiotics in open fractures.

Additional coverage for gram-negative organisms was an area with significant variability among respondents. However, as the severity of the open fracture increased, the proportion of respondents who agreed that additional gram-negative coverage was necessary also increased (Fig. 2).

Timing of antibiotic treatment

Almost all participants reported that the first dosage of PAP in open fractures was generally administered as soon as possible upon arrival to the emergency department (86%, n = 1033). A small proportion of surgeons (3%, n = 34) reported pre-hospital administration at the scene of an accident or during transport to the hospital. These respondents were mainly from the Netherlands (21%, n = 7), from the United Kingdom (UK) (15%, n = 5), and from the United States of America (USA) (12%, n = 4). Eight per cent of the respondents (n = 95) administered antibiotics together with

Table 1
List of top 10 first choice antibiotics in open fractures (all types).

Rank	Choice of antibiotics	n	%
1	Cefazolin + Gentamicin	154	12.9%
2	Cefazolin	116	9.7%
3	Cefuroxime	65	5.4%
4	Cefazolin + Gentamicin + Metronidazole	56	4.7%
5	Cefuroxime + Gentamicin + Metronidazole	38	3.2%
6	Cefazolin + Gentamicin + Clindamycin	31	2.6%
7	Cefuroxime + Metronidazole	26	2.2%
8	Gentamicin	24	2.0%
9	Cefuroxime + Gentamicin	24	2.0%
10	Gentamicin + Metronidazole	19	1.6%

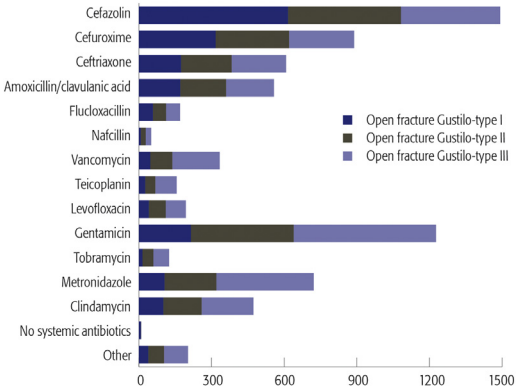

Fig. 1. Antibiotics regularly used by respondents as first choice for systemic perioperative prophylaxis in open fractures. Results shown as absolute numbers of respondents (n=1179, multiple answers possible).

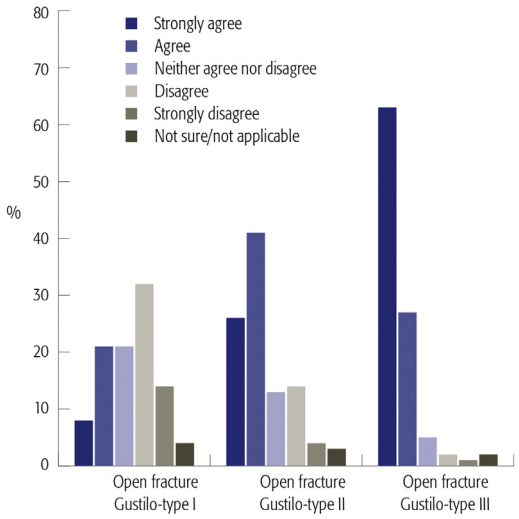

Fig. 2. Statement: "Additional coverage for gram-negative organisms is important in..." Results shown as percentage of all respondents (n=1197).

narcotics, approximately 30 min before surgery. Only 2% (n = 26) administered antibiotics after debriding or taking several biopsies in the operation room.

Antibiotic treatment duration

In closed fracture cases, PAP was discontinued mainly once surgery was completed (44%, n = 530) or after 24 h of the procedure (38%, n = 460) (Fig. 3). Still, some participants reported continuation of antibiotics in closed fractures for an additional 48 h (11%, n = 137) or even 72 h (7%, n = 78) after surgery. An appreciable proportion of respondents (7%, n = 83) reported giving no antibiotics at all after fracture fixation in closed fractures.

With regard to open fractures, the survey results showed a trend for longer postoperative regimens with increasing severity. In GA type IIIB and IIIC, a clear majority administered antibiotics for an additional 72 h or even longer (83%, n = 986).

The statement *'The more extensive the soft tissue injury is in open fractures, the longer the antibiotic regimen should be to prevent infection'*, raised controversy among the participants. Half of the respondents agreed with the given statement ('agree': 35%, n = 421; 'strongly agree': 16%, n = 190) (Fig. 4). However, 14% (n = 169) neither agreed nor disagreed and one third of respondents completely disagreed (26%, n = 312) or even strongly disagreed (8%, n = 98).

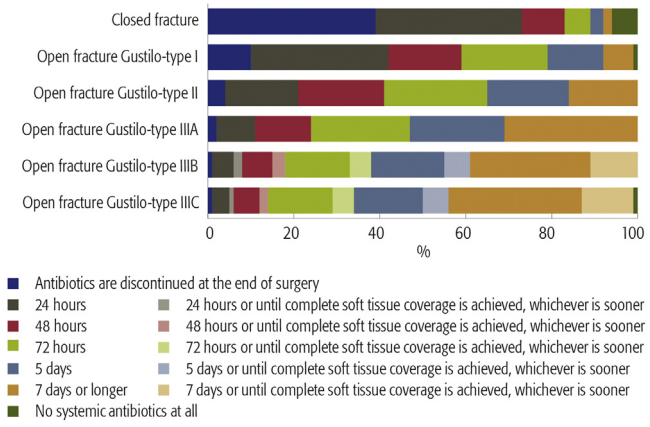

Fig. 3. Statement: "The more extensive the soft tissue injury is in OPEN fractures, the longer the antibiotic regimen should be to prevent infection." Results shown as percentage of all respondents (n=1197).

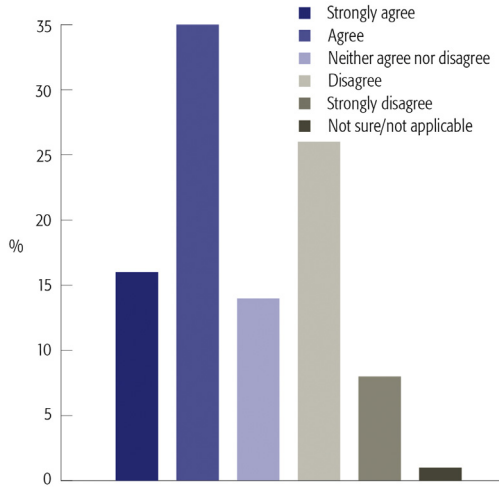

Fig. 4. Statement: "The more extensive the soft tissue injury is in OPEN fractures, the longer the antibiotic regimen should be to prevent infection." Results shown as percentage of all respondents (n=1197).

Most participants (71%, n = 849) agreed with the statement *'The optimal duration of systemic perioperative antibiotic prophylaxis in the treatment of open fractures has not been well defined in the literature'* showing that there is a need for clear guidelines on the optimal duration of perioperative antibiotic treatment (Supplementary Fig. 1, online data).

When faced with the statement *'Antibiotic prophylaxis regimens for open fractures at my workplace vary depending on the doctor who is treating the patient'*, respondents were divided. Almost half of them agreed with the statement (agree: 34%, n = 410; strongly agree: 12%, n = 142) and the other half disagreed (disagree: 27%, n = 326, strongly disagree: 17%, n = 207). Only 8% (n = 100) neither agreed nor disagreed.

Antibiotic dose adjustment

When asked whether the antibiotic dosage was adjusted to the patient's body weight, orthopaedic surgeons showed no consensus: 'in most of the cases' (23%, n = 272), 'sometimes' (24%, n = 285), and 'rarely' (23%, n = 279). Overall, 19% (n = 224) always adjusted the antibiotic dosage to the patient weight and 11% (n = 130) reported that they never did this. Less than one per cent (n = 7) chose 'not sure/not applicable'.

Local anti-infective agents

When asked, *'Do you regularly apply any of the following local anti-infective carriers at the surgical site as a prophylactic measure?'* the most often-mentioned responses for closed fractures were 'antimicrobial wound dressings' (11%, n = 131), 'suture material with antimicrobial coating' (6%, n = 68), and 'antibiotic as powder (e.g. vancomycin)' (3%, n = 35) (Fig. 5). In open fractures, the proportion of local anti-infective carriers overall was higher, and all options received additional votes with increasing severity of the injury (Fig. 5). In GA Type I and II open fractures, antimicrobial wound dressings were also mentioned most often by 11% (n = 131) and 21% (n = 252) of respondents, respectively.

In Type IIIB and IIIC open fractures, cement beads with antibiotics (33%, n = 394) and antimicrobial wound dressings (30%, n = 356) were used most often. 'Antibiotic bone void fillers' were also voted frequently (19%, n = 228). However, this option received fewer votes in GA Type IIIA open fractures (13%, n = 156). Furthermore, 'antibiotic as powder' was mentioned by a relevant number of respondents (GA Type IIIA: 13%, n = 157; GA Type IIIB: 17%, n = 209; and GA Type IIIC: 18%, n = 210). Finally, the use of an 'Antibiotic impregnated collagen fleece/sponge' was also reported among respondents (GA type IIIA: 12%, n = 147; GA Type IIIB: 14%, n = 171; GA Type IIIC: 16%, n = 186).

Timing of surgery in open fractures

For the question *'After an accident, what is the longest time that you regard as tolerable in your practice until performing the first debridement in an open fracture? (Assume that the patient received early systemic prophylactic antibiotics, is stable and fit for surgery)'*, 47% of the participants (n = 565) considered 6 h as the maximum tolerable time in open fractures from injury until the first surgical debridement; although, there was also a considerable proportion of respondents that chose 12 h (16%, n = 186) or 24 h (18%, n = 220). An even shorter duration of 2 h was favoured by 11% (n = 131) of the respondents. Very few respondents considered 48 h (1%, n = 15) or even longer (1%, n = 15) as tolerable.

Irrigation

The most frequently used irrigation fluid in all open fractures was normal saline (89%, n = 1070) (Fig. 6). Povidone-iodine solutions were mentioned by almost one quarter of the respondents in GA Type I (24%, n = 293). This number increased with the increasing severity of the open fracture to 36% (n = 432) in GA Type III fractures. Hydrogen peroxide followed with 14% (n = 172) in GA Type I, and increased to 30% (n = 349) in GA Type III injuries. Chlorhexidine was mentioned by 10% (n = 122) for GA Type I and increased to 15% (n = 175) in GA Type III fractures. All other irrigation fluids were mentioned by fewer than 10% of all participants.

Over half of the respondents (55%, n = 658) used a low pressure with a bulb syringe to irrigate open wounds. One third (30%, n = 361) used very low-pressure irrigation ('gravity flow') and a minority (15%, n = 178) used pulsed high-pressure irrigation 'Jet-Lavage'. With regard to the amount of irrigation fluid used in GA type III open fractures, Fig. 7 shows the bimodal distribution of the volumes reported, one peak at 4–6 litres (24%, n = 286) and another at 8–10 litres (24%, n = 282). All other volumes were mentioned less frequently.

Discussion

Although open fractures are a well-known clinical challenge for orthopaedic trauma surgeons worldwide, there is a lack of standardised, internationally accepted, treatment guidelines. The objective of this survey was to provide an overview of the current international clinical practice in orthopaedic trauma surgery with respect to prevention of FRI.

The first topics of this survey focused on type, timing and duration of PAP. As expected, cephalosporins were considered the most commonly used antibiotic for prevention of FRI in closed and open fractures. With increasing injury severity, combinations of different antibiotics are being prescribed more frequently. In particular, the administration of gentamicin in GA Type III open fractures is common. This said, overall, 13 different antibiotics were prescribed, confirming the enormous heterogeneity with respect to the type (i.e. choice of systemic antibiotics) of PAP.

Three different PAP protocols have been proposed in the literature. First, the Surgical Infection Society recommends the use of a short course of a first generation cephalosporin for all GA types without extended coverage of the gram-negative spectrum [5]. A second protocol consists of the provision of gram-negative coverage for all types of open fractures. This approach originated from Patzakis and Wilkins who reported that combination therapy in open tibia fractures reduced the infection rate (4.5%, n = 5 of 109) compared to cephalosporins only (13%, n = 25 of 192) [6]. Finally, multiple authors and guidelines have proposed gram-negative coverage only for GA Type III injuries. This is recommended due to

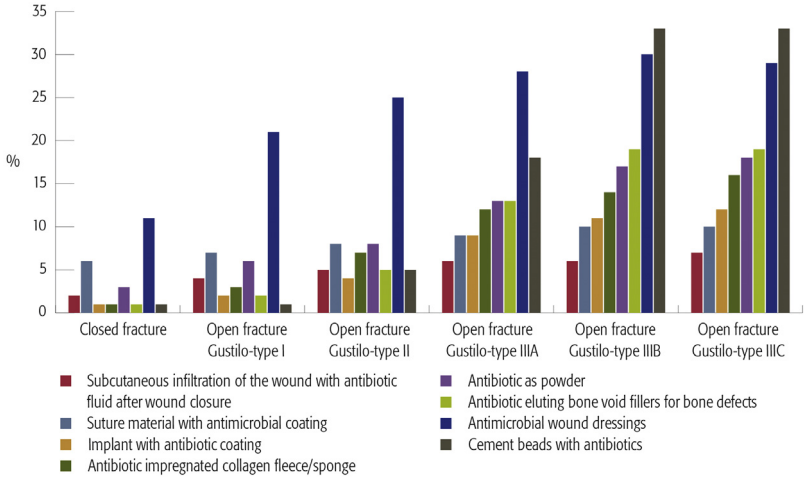

Fig. 5. Choice of local anti-infective agents at the surgical site as a prophylactic measure. Results shown as percentage of all respondents (n=1197, multiple answers possible).

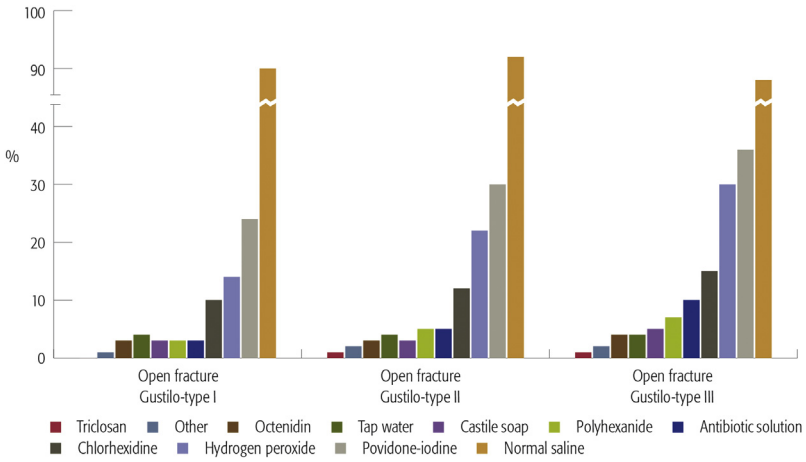

Fig. 6. Choice of irrigation fluid during the initial debridement in open fracture management. Results shown as percentage of all respondents (n=1197, multiple answers possible).

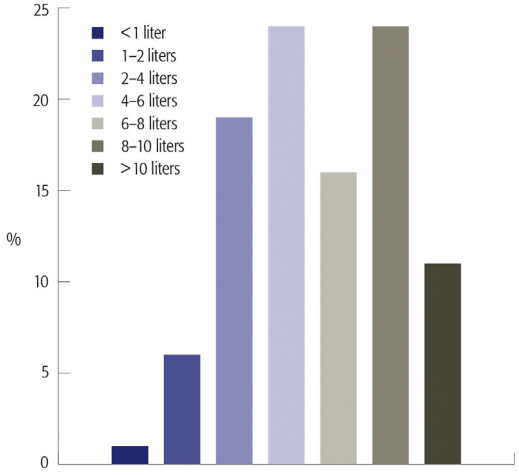

Fig. 7. Amount of irrigation fluid used during the initial surgery of a GA type III open fracture. Results shown as percentage of all respondents (n=1197).

the results of the study by Gustilo et al. that demonstrated that 77% of the FRIs in GA type III fractures were caused by gram-negative organisms [7]. The Eastern Association for the Surgery of Trauma (EAST) and the British Orthopaedic Association/British Association of Plastic, Reconstructive and Aesthetic Surgeons (BOA/BAPRAS) guidelines, also recommend the addition of aminoglycosides in GA Type III open fractures [8,9]. Furthermore, Vasenius et al. demonstrated adequate prevention with clindamycin and cloxacillin in GA Type I and II open fractures, but unacceptably high infection rates (29.0% and 51.8%, respectively) in GA Type III open fractures [10].

The importance of adequate timing of antibiotic prophylaxis is quite uniformly accepted worldwide. In 1989, Patzakis and Wilkins were the first to demonstrate a higher risk of infection when antibiotic delivery was delayed longer than 3 h after injury [6]. Animal studies supported these findings. Penn-Barwell et al. found a significant detrimental effect on the infection rate with *Staphylococcus aureus* in a rat open fracture model if antibiotics were delayed by 6 or 24 h regardless of the timing of the initial debridement [11]. The timing of antibiotics had a more significant effect on the number of positive samples compared to earlier surgery. Lack et al. demonstrated that administering antibiotics later than 66 min after the accident was an independent risk factor for FRI in patients, with an odds ratio of almost 4 in a retrospective study of 137 GA Type III open tibia fractures [12]. Therefore, pre-hospital administration may help improve outcomes of severe open fractures [12,13]. According to data from this survey, it appears that early in-hospital administration of antibiotics is a very common practice (86%, n = 1033). The earliest possible administration by rescue services at the scene of the accident would be desirable, however, this regimen was reported only by a very small number of surgeons (3%, n = 34), mainly from the Netherlands, the UK, and the USA. Thomas et al. reported that the administration of antibiotics by helicopter emergency medical services crews to patients with open fractures was feasible and may decrease the time to antibiotic initiation by 30 min [13]. However, no significant difference in outcomes was observed in this small study. A recent systematic review by Whitehouse et al. concluded that there was currently insufficient evidence to support the routine pre-hospital administration of antibiotics compared to delivery in hospital for patients with an open fracture of the lower limb [14].

A number of orthopaedic trauma surgeons (11%, n = 135) reported not using any systemic antibiotic for prophylaxis in closed fractures. This phenomenon was not country-specific nor related to the lack of professional experience. It is a surprising finding, as one would expect a strong consensus with respect to this topic. Evidence for the use of systemic antibiotic prophylaxis for 'clean' surgery is robust, as numerous studies have reported PAP to be safe and effective in preventing FRI [15–18].

There seems to be a lack of consensus among orthopaedic trauma surgeons with respect to PAP duration. As expected, for open fractures there is a trend towards longer regimens with increasing severity of the injury (Fig. 3). Compared to GA type I injuries, for example, a higher number of respondents administers systemic antibiotics for seven days or even longer in patients with GA type III open fractures. Overall, it is remarkable to see this high level of heterogeneity between PAP protocols (i.e. type and duration), not only on an international scale, but also locally. A large proportion of respondents stated that they experience heterogeneity of applied antibiotic regimens in the management of open fractures directly at their own workplaces (agree: 34%, n = 410; strongly agree: 12%, n = 142). This finding was not country specific and was independent of the hospital size. It appears that standard procedures for open fracture management have not been fully established. This may be attributed to the fact that open fractures are complex injuries that need to be addressed individually and the absence of clear evidence from the literature to guide all details of management. However, the continuity of basic features of treatment is relevant for efficiency and treatment

success and allows scientific evaluation of certain aspects of care. To date, clinical studies have not demonstrated any clear advantages of specific regimens due to their retrospective design, heterogeneity of the patient population, and treatment-related factors (i.e. protocols). For highly contaminated wounds, preclinical studies have shown that a 72-hour regimen of postoperative antibiotics might be superior for preventing FRI compared to a 24-hours regimen [19]. The optimal duration of antibiotic administration post-surgical debridement, however, remains controversial and probably varies anywhere from 24 to 72 h [20]. Evidence to continue PAP beyond 72 h is currently lacking. The majority of participants (71%) agreed with the statement that the optimal duration of systemic PAP in open fracture cases has not been well defined, showing the need for the development of clear guidelines on this topic as the absence of an international consensus remains problematic in orthopaedic trauma surgery today (Supplementary Fig. 1, online data).

Substantial heterogeneity also exists in the orthopaedic trauma community with regard to adjusting prophylactic antibiotic dosage to the patient's body weight. Only 41% (n = 496) of respondents adjust the dosage 'always' or 'most of the time'. Overall, dosing generally assumes a mean body weight of 75 kg and although administration of fixed dosages (e.g., 1.5 g of cefuroxime) for each patient is more convenient for physicians, for patients weighing significantly more than 75 kg this dosage might not be sufficient [21].

The use of local anti-infective agents seems to vary significantly, primarily depending on injury severity (Fig. 5). In closed fractures, only a minority of surgeons use local anti-infective carriers. Interestingly, the most recent WHO guidelines recommend the use of triclosan coated sutures 'independent of the type of surgery' which also refers to the treatment of closed fractures [22]. With regard to locally-administered anti-infective agents it is remarkable that, except for 'antimicrobial wound dressings', all other options were chosen by fewer than 10% of respondents in GA Type I and II open fractures, which conveys the impression that orthopaedic surgeons regard GA Type I and II as more similar to closed fractures than to GA Type III open fractures in terms of treatment using local anti-infective carriers (Fig. 5). The potential of local antibiotics together with systemic antibiotics to reduce infection rates in severe open fractures has been well established in the literature in both clinical [23–25] and preclinical studies [26–28]. A recent systematic review by Morgenstern et al. found a risk reduction in FRI of 11.9% if additional local antibiotics were given prophylactically for open limb fractures [29]. In our survey, cement beads with antibiotics were the most common method for local antibiotic delivery and were used by 33% of respondents in GA type IIIB and IIIC open fractures.

Thorough surgical debridement in the operation room remains the cornerstone in prevention of FRI [30]. All devitalised tissue and foreign bodies need to be removed from the wound as they provide growth conditions for microorganisms. The timing of debridement was historically believed to play an important role, resulting in the 'six hour rule', whereby the target for surgery is six hours after the accident [31]. Our data reveals, that this rule impacts most surgeon's practices and beliefs, as almost half of all respondents (47%, n = 565) regarded six hours as the maximum tolerable allowable time before debridement. Patzakis et al. concluded in 1989 after reviewing 1104 open fractures that there was no significant difference in infection rates in open fractures that were debrided within 12 h (6.8%, 27 of 396) and in those debrided after 12 or more hours after injury (7.1%, 50 of 708) [6]. Pollack et al. did not identify any significantly higher infection rates in a study of 307 patients with severe open fractures of the lower extremity even after more than 10 h from injury to debridement [32]. In a prospective study of 736 patients with open fractures Weber et al. found no association between infection rates and delayed debridement [33]. The development of infection was correlated with the severity of the injury and the anatomic location (i.e., the tibia). However, Hull et al. demonstrated a linear increase in the infection rate of 3% per hour of delay for Type II and III open fractures in a consecutive series of 364 patients with 459 open fractures [34]. Although there is currently no robust scientific evidence for a 'six hour rule', an early surgical debridement in combination with fracture fixation in severe open fractures appears to be reasonable, not only for patient comfort but also because biofilm formation begins right after contamination. Moormeier et al. characterized this early phase of biofilm formation in *Staphylococcus aureus* as a 'multiplication phase', after which distinct foci of robust biofilm growth are formed [35].

Normal saline is most often used as irrigation fluid in the management of all open fractures (Fig. 6). This practice is supported by current evidence as other solutions bear the risk of increased cytotoxicity, and result in irritation, which is counterproductive in the prevention of infection [36–39]. Anglen et al. prospectively studied 400 patients with 458 open fractures and found a higher risk of wound healing complications in the group that received normal saline with bacitracin compared to the group receiving normal saline with castile soap (9.5% vs. 4%; p = 0.03) [40]. The fluid lavage of open wounds trial (FLOW) found normal saline to result in fewer re-operations compared to the use of castile soap [41]. The recent extension of the FLOW trial did not find any significant differences in health-related quality of life one-year post injury in 1680 participants that received either a saline or soap solution for wound irrigation [42]. On the basis of current evidence, normal saline appears to be the agent with the best benefit/risk profile.

Regarding irrigation pressure, over half of the respondents (55%, n = 658) used low pressure with a bulb syringe to irrigate the open wound and one third (30%, n = 361) used very low pressure irrigation 'gravity flow'. This practice is also substantiated by the FLOW trial, as low irrigation pressure was found to be equally effective as compared to high-pressure lavage [41]. Pulsed high-pressure irrigation 'Jet-Lavage' is expensive and not available in many countries. Only 15% of respondents (n = 178) use 'Jet-lavage' for the debridement of open fracture wounds.

The bimodal distribution regarding the amount of irrigation fluid, with two peaks at 4 to 6 litres (24%, n = 286) and at 8 to 10 litres (24%, n = 282), conveys the impression that the decision on the volume used is merely based on the pre-fabricated bag sizes that are offered (Fig. 7). It is well known that the number of bacteria in the wound decreases with an increasing amount of irrigation fluid [43]. Interestingly, the amount of fluid that was most commonly used by trauma surgeons, described in a survey from 2008 by Petrisor et al., was smaller and ranged between 3 to 6 litres for GA Type III open fractures [44]. However, the optimal amount of irrigation fluid remains unknown.

One of the most important limitations of this study is the high percentage of non-responders, which of course can induce a non-responder bias. This high number was presumably caused by the blast e-mail sent to over 80,000 e-mail addresses without sending a reminder e-mail, which is a known issue also encountered in a previously published survey [45]. Furthermore, many e-mail addresses were probably no longer active. Therefore, with respect to the response rate calculation, only the 26,597 recipients that opened the e-mail were taken into account. Despite the high number of non-responders, this study has important advantages, namely the overall high number (1197) of responding surgeons in combination with the worldwide coverage of respondents. Although similar smaller surveys have been conducted previously [46], to the best of our knowledge, this is the first survey to include such a high number of surgeons. Although another limitation seemed to be the high percentage of respondents from one country

(i.e. India), subgroup analysis excluding the results from this country did not change the overall results of the survey.

Conclusion

This international survey provided an overview of clinical practice in FRI prevention, particularly in open fracture cases. The treatment of these serious injuries remains heterogeneous. A major issue is the lack of consensus concerning type and duration of PAP. Furthermore, there is no agreement on the indication and type of local anti-infective agents. Overall, it is unknown what the repercussions are of this lack of internationally accepted guidelines on daily clinical practice, but it is clear that standardised treatment protocols are preferable in the current medical landscape.

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Disclosures

This manuscript is not under simultaneous consideration for publication by any other journal.

Conflict of interest statement

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.injury.2019.04.013.

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