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Provisional Reprocessing of Medical Devices in Field Hospitals: Evaluation of Chemical Approaches for Feasibility and Effectiveness

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Abstract

Objectives: Field hospitals are deployable hospitals that treat patients directly on site before they are transported to permanent medical facilities. The supply of sterile surgical instruments is important, but not every field hospital is equipped with a sterile processing department. This concept therefore attempts to test a method of reprocessing surgical instruments under field conditions that can at least provide a provisional form of disinfection in case of logistic breakdowns.

Methods: Development, testing, and evaluation of a provisional chemical reprocessing procedure for reusable surgical instruments using hydrogen peroxide. The evaluation was carried out visually, microbiologically, and with regard to material damage.

Results: The concept is easy to implement but requires thorough training. The reprocessed surgical instruments were free of residual protein, showed no bacteriological growth, and were not damaged by the chemical reprocessing even after 10 cycles.

Conclusions: Provisional reprocessing of reusable surgical instruments seems possible using high-level chemical disinfection with hydrogen peroxide (3% for 150 minutes or 7.5% for 30 minutes) in case of necessity due to logistic breakdowns and patients that need immediate treatment. In addition, a multibarrier approach that includes hygiene measures and antibiotic stewardship is required to effectively reduce the risk of surgical site infections.

Introduction

Field hospitals are deployable hospitals that take care of patients on site before they can be transported to permanent medical facilities.[1] They can be planned, deployed, and operated for military or humanitarian purposes, for example, in wars, natural or man-made disasters, and even in epidemic or pandemic scenarios.[2–6]

Among many other challenges, the supply of sterile surgical instruments (SIs) to a field hospital is very important, because sterile SIs have been an essential measure of infection prevention and control in medical facilities for over 150 years.[7] Medical devices (MD) are categorized into three categories according to their intended use[8–11]:

- "Noncritical MD" (like stethoscopes) come into contact only with healthy skin,
- "Semi-critical MD" (like endoscopes) come into contact with pathologically altered skin or mucous membrane,
- "Critical MD" (like SI) penetrate the skin barrier and come into contact with blood or organs.

Table 1 summarizes the necessary level of disinfection or sterilisation for the different categories of MD and what this reprocessing is intended to counter.

SIs are classified as "critical MD" and have therefore to be sterilized. In regular hospitals, thermal or chemical processes are used for this purpose. The most common thermal process is steam sterilization (autoclaving), often at temperatures of 121°C or 134°C.[9,10] Various chemicals are available for chemical sterilization, which, when used in different dosages and left to act for different periods, lead to different sterilization effects.[11(pp.22-36)] What all these methods have in common is that successful reprocessing is associated with high structural, technical, personnel, and procedural requirements.[12]

Table 1. Necessary levels of disinfection or sterilisation for the three categories of MD according to CDC[17]

Medical device	Level of disinfection/ sterilization	Effect against[11(p. 18)]
Noncritical MD	LLD	All vegetative bacteria (except tubercle bacilli), lipid viruses, some nonlipid viruses, and some fungi, but not bacterial spores
Semicritical MD	ILD	All agents as low-level disinfection and tubercle bacilli, but not bacterial spores
	HLD	All agents as intermediate-level disinfection, all viruses and bacterial spores with a SAL of $>10^{-6}$
Critical MD	Sterilization	All agents as high-level disinfection and bacterial spores with a SAL of $\leq 10^{-6}$

Abbreviations: *CDC*, Centers for Disease Control and Prevention; *HLD*, high-level disinfection; *ILD*, intermediate-level disinfection; *LLD*, low-level disinfection; *MD*, medical devices; *SAL*, sterility assurance level.

These requirements are often not met in field hospitals.[13] North Atlantic Treaty Organization (NATO) defines the "Role 2B" with seven core modules as the smallest field hospital. Sterilization is an enhanced module that is optionally available in a "Role 2E" and is only mandatory from "Role 3."[3,4] World Health Organization (WHO) recommends disposable material or basic steam autoclaves for "Emergency Medical Teams (EMT) Type 1" and a sterilization capability that meets all requirements from "EMT Type 2."[14]

Field reports are rare and tend to emphasise medical performance,[15] so practical experiences with reprocessing in field hospitals are hard to find. In Haiti in 2010, it was reported that one field hospital was sterilized using autoclaves, while a second only processed SI using "high-level disinfection" (HLD).[2]

This concept therefore attempts to test a method of reprocessing SI under field conditions that can at least provide a provisional form of disinfection in the event of the absence or unplanned failure of a sterile processing department (SPD).

Methods

Basic Information About the Field Hospital

The reprocessing concept was introduced in a field hospital that essentially consisted of a container-based operating theatre (Figure 1, A) and an attached tent (Figure 1, B) and was thus comparable to a NATO "Role 2F"[4] or a WHO "EMT Type 1 Fixed."[14] This field hospital can provide surgical capacity for 10 patients within 24 hours without external supply. In the operating theatre, a washbasin (Figure 2, A) with up to 700 L of chlorinated drinking water according to WHO standards[16] is available via a supply pallet (Figure 1, C).

Surgical Instruments and Test Soiling

Reusable SI of various shapes and sizes were selected for the test soiling, with particular attention paid to including challenging instruments such as scissors, serrated forceps, and surgical spoons with grooves (for details see Supplement S1).

The test soil, a mixture of raw minced meat, soil, blood, and *Escherichia coli* from sewage, was applied by immersing the instruments. The instruments were then stored at 20°C for 24 hours to allow the test soil to dry. This procedure was used to simulate the worst-case scenario of dried-on contamination.

Figure 1. The field hospital. A: Lorry with operation theatre container. B: Tent for the pre- and postoperative management of patients, including the reprocessing area. C. Lorry with supply pallet (including 700 liters of chlorinated water).

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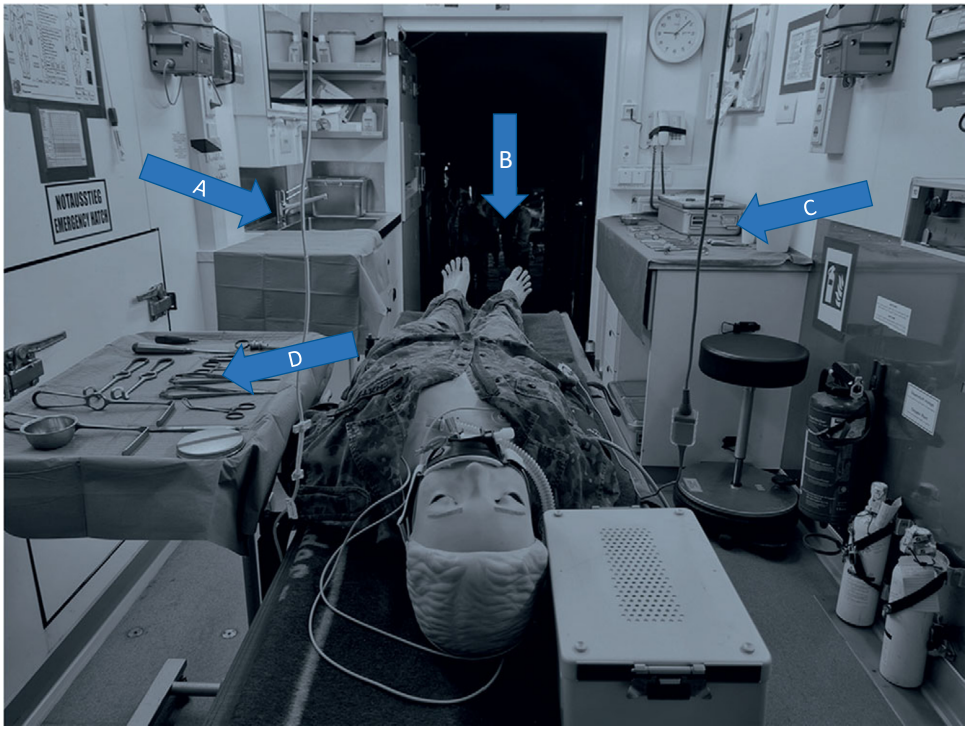

Figure 2. Interior view of the operating room container (Figure 1, A). A: Unclean area including washbasin for precleaning of used SI. B: Connecting element to the tent (Figure 1, B). The reprocessing area is located directly at the end of the connecting element on the left. C: Clean area, preparation of the SI. D: Operating area, use of the SI.

Reprocessing Agent

Hydrogen peroxide (H_2O_2) 3% was chosen as the agent for the reprocessing for three reasons: firstly, H_2O_2 3% is readily available in Germany and thus sufficiently available even in emergency situations; secondly, H_2O_2 3% is recommended as a dip disinfectant for the domestic environment for certain MDs[17]; and thirdly, practical experience is available from Haiti, where H_2O_2 2% was used for HLD.[2]

Reprocessing Process and Area

The reprocessing concept consisted of seven steps: pretreatment at the point of use, transportation, cleaning, inspection, chemical disinfection, drying, and storage.

1. Pretreatment at the point of use was carried out immediately after use. For this purpose, the used SI was rinsed under running chlorinated water (0.2-0.3 mg of free chlorine per liter) in the operating room container (Figure 2, A) and mechanically cleaned using a brush (model 09320, STERIS KeySurgical, Cologne, Germany). Each SI was brushed for at least 5 minutes under the water jet (6 L per minute) and continued until it was visually clean.
2. The pretreated SIs were transported to the reprocessing area in the tent via the connection element (Figure 2, B).
3. Cleaning was performed in a 20-L ultrasonic bath (Figure 3, A) with Deconex® PROZYME ACTIVE (Borer Chemie, Zuchwil, Switzerland) for 10 minutes at 45°C. Afterward, the cleaned SIs were rinsed of cleaning agent residues by immersion in water according to manufacturer's specifications (Figure 3, B). Ultrasonic baths are recommended by the WHO[18] as a cleaning method and are therefore found in many field hospitals, as well as in NATO "Role 2E."[3]
4. After cleaning, the SIs were checked for cleanliness and damage. Clean SIs were processed further; visually dirty instruments were cleaned again with a brush and via ultrasonic bath, and damaged SIs were discarded.
5. Disinfection was performed with H_2O_2 3% (Purux, Laaber, Germany) via immersion for 30 minutes (Figure 3, C).
6. The disinfected SI were air-dried on a sterile surface.
7. For short-term storage (about 1 hour), the dry SI were sterile covered; for longer storage (up to 24 hours), the dry SI were stored in ethanol 96% (Figure 3, D).

Pretreatment was carried out by the "circulating nurse" of the surgical team. This employee is not a nurse, but a paramedic with an internal further qualification in SI management.

All other process steps were carried out by another paramedic who had been trained in the reprocessing of SI through an internal training programme. This training program included a 2-hour theoretical introduction followed by five practice sessions under the supervision of a qualified sterile processing technician providing individual coaching. The training qualifies participants exclusively for the reprocessing of SI in accordance with the concept described here.

Evaluation of the Cleaning Result

The cleaning performance was evaluated visually for all processed MDs. In addition, four processed batches of randomly chosen 10 SIs each were examined for residual proteins using the biuret method with BCA according to ISO 15883.[19] Randomly means here that 10 SIs from supplement S1 were combined into one batch. The examination was carried out by an accredited laboratory (Normec Hybeta GmbH, Münster, Germany). Sampling was carried out in accordance with the standard operating procedures of the laboratory.[20] Cleaning was considered successful if the warning level of 100 µg per SI was not exceeded. A Mann-Whitney U test was performed to test for statistical significance of the results, whereby alpha was set to 0.05.

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Figure 3. Reprocessing area. A: Three ultrasonic baths. B: Immersion bath with water. C: Immersion bath with H_2O_2. D: Two storage boxes with 96% ethanol.

Evaluation of the Disinfection Result

The success of the disinfection was qualitatively evaluated visually and by taking swabs from processed SI, spreading them on blood agar plates, and incubating them at 37°C for 48 hours. Three different times of examination were chosen for this:

Each of 10 randomly chosen SIs was examined

- immediately after reprocessing,
- 1 hour after reprocessing, storage was carried out under sterile covers on a sterile surface,
- 24 hours after reprocessing, storage was carried out in 96% ethanol.

Randomly means here that 10 SIs from supplement S1 were combined into one batch. Successful disinfection was assumed when no growth of bacteria was detectable on the blood agar plates.

Evaluation of Material Compatibility

The material compatibility was evaluated optically and microscopically on three selected SIs (clamp, scissors, forceps). The selected SIs were contaminated up to 10 times and reprocessed, so that a total of 30 SIs were examined. All examined SIs were also evaluated microbiologically in order to assess the influence of possible material changes on the disinfection success.

Results

Cleaning Result

In the control group of 10 non-reprocessed SIs, the median concentration was 5183 µg residual protein per SI (minimum: 2810 µg, maximum: 16,213 µg). The 40 reprocessed SIs were all visually clean and had a residual protein value below the limit of quantification of 5 µg per SI ($z = 6.943$, $P = .000$). Figure 4 summarizes the results.

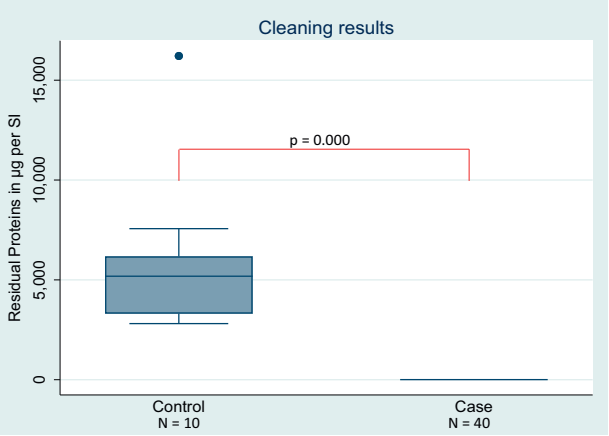

Figure 4. Boxplots of residual proteins of cleaned SI ("Case") and a control group of soiled instruments ("Control"). A Mann-Whitney U test was performed to test for statistical significance. All values of the "Case" group were below the limit of quantification of 5 µg per SI but were set to 5 µg per SI for graphical and mathematical reasons in this figure.

Disinfection Result

The disinfection result is positive at all three test times (immediately after reprocessing, 1 hour after reprocessing, 24 hours after reprocessing): no bacterial growth could be detected in any of the samples, while in the control group all SIs showed abundant growth of Enterobacteriaceae and sparse growth of aerobic spore formers.

Immediately after reprocessing and 1 hour after reprocessing, all of the SIs were visually clean, while all of the SIs in the control group were dirty; 24 hours after reprocessing, only 6 of the SIs were visually clean, while 4 SIs were visually dirty.

Table 2 summarizes the results.

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Table 2. Disinfection results

Time	Visual result	Bacterial result
Control	Dirty (10/10)	Numerous Enterobacteriaceae, sparse aerobic spore formers (10/10)
Immediately after reprocessing	Clean (10/10)	No growth (10/10)
1 hour after reprocessing	Clean (10/10)	No growth (10/10)
24 hours after reprocessing	Clean (6/10) Dirty (4/10)	No growth (10/10)

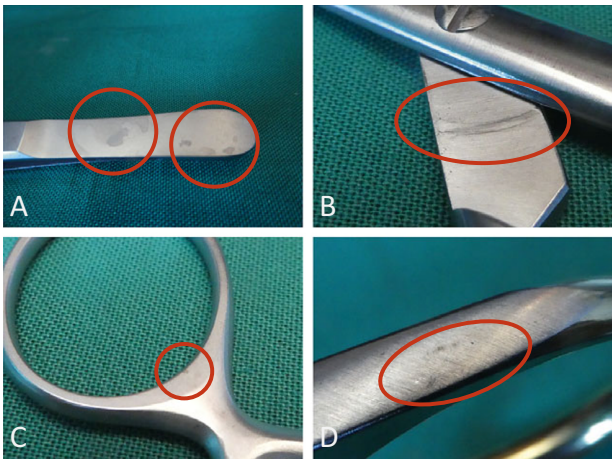

Figure 5. Results of the material compatibility evaluation. A: Water stains (example from cycle 3). B: Signs of rubbing (example from cycle 1). C: Contact corrosion (cycle 5). D: Rubbing point that could lead to contact corrosion (cycle 10).

Material Compatibility

The instruments are still fully operational after the cycles performed. There is no recognizable trend of deterioration in their condition over the 10 reprocessing cycles performed. Some SIs showed uncritical water stains or signs of rubbing. One SI had contact corrosion (cycle 5), and 1 SI had a rubbing point that could lead to contact corrosion (cycle 10). These instruments are shown in Figure 5.

No bacterial growth could be detected in any of the reprocessed SI samples.

Limitations

This concept has 3 major limitations. At first, no general accepted or validated test contaminant was used. Such test contaminants are commercially available and would be necessary to validate the presented reprocessing method for legal proposes. The main aim is to be able to calculate a "log-reduction" to quantify the effectiveness of the presented reprocessing method. However, since the bacteriological evaluation did not show any growth of bacteria, it has at least been qualitatively proven that the reprocessing concept is effective. This qualifies this study as a successful proof-of-principle or pilot study.

At second, the presented reprocessing method wasn't analyzed in regard of its antiviral effectiveness. It may be possible and likely that it has no sufficient antiviral effect, in special against nonenveloped viruses like Hepatitis B virus or human immunodeficiency virus. Since these viruses are transmitted via blood and could thus lead to nosocomial transmission if reprocessing is not effective, this limitation is serious. However, HLD is, by definition (Table 1), effective against all viruses, so that even if testing for virucidal activity is not carried out, it can be assumed that there is sufficient viral efficacy. Whether this concept is actually a HLD is reviewed critically in the discussion.

At third, the presented concept is limited to SI as a subgroup of "critical MD." Although SIs have the highest reprocessing requirements due to their intended use, they are made of steel, so they are relatively insensitive to heat, moisture, and chemicals. Noncritical medical products or personal protective equipment are generally much easier to reprocess but require completely different processes, such as ultraviolet radiation.[21,22]

Discussion

This concept successfully tested a method of provisional reprocessing SI under field conditions in the event of the absence or unplanned failure of an SPD. Some fundamental questions that arise in this context will be discussed here.

Disposal vs. Reprocessing

Not every field hospital has an SPD. NATO "Role 3/4" and WHO "EMT Type 2/3" are large field hospitals that are only partially mobile and are set up in containers or a fixed infrastructure.[3,4,14] This ensures that an SPD can meet all structural, technical, personnel, and procedural requirements and that MDs can be professional reprocessed.

In a military context, however, these field hospitals are easy targets for drones, artillery, and missiles. Current experience with the systems used in Ukraine shows that ranges of up to 500 km are possible.[23] Accordingly, these field hospitals will be set up at a great distance from the front line. The smaller and more mobile field hospitals of NATO "Role 1/2," on the other hand, will operate much closer to the front line. They will therefore be set up in tents or basements where they are harder to see or hit. It is therefore unlikely that these field hospitals will be able to provide professional reprocessing of MDs, which is why they either have to be equipped with disposable material or used MDs have to be collected by logistics units and returned after reprocessing in NATO "Role 3/4." In both cases, the field hospitals of NATO "Role 1/2" are therefore dependent on a functioning logistics system, which can be at risk in such scenarios, and even in nonwar scenarios, with flooded roads or destroyed bridges. In this respect, the WHO "EMT Type 1" can also face the problem of having to perform provisional reprocessing.

At this point, it pays off if the field hospital has reusable SI that can be reprocessed in principle, or at least disposable SI made of metal instead of plastic. However, this concept also shows that the quality of metal disposable SI may also be less than ideal, and even before the first use, there may be problems with paint crumbling off (Figure 6). It cannot be ruled out that storage conditions in tents and basements are not good in terms of temperature and humidity, causing the colour to lose stability. The use of single-use products in these field hospitals must therefore be fundamentally questioned. Studies comparing single-use and reusable SI are rare and often refer to the economic or ecological advantage over the entire life cycle,[24–28] but not to the actual product quality. In studies on the

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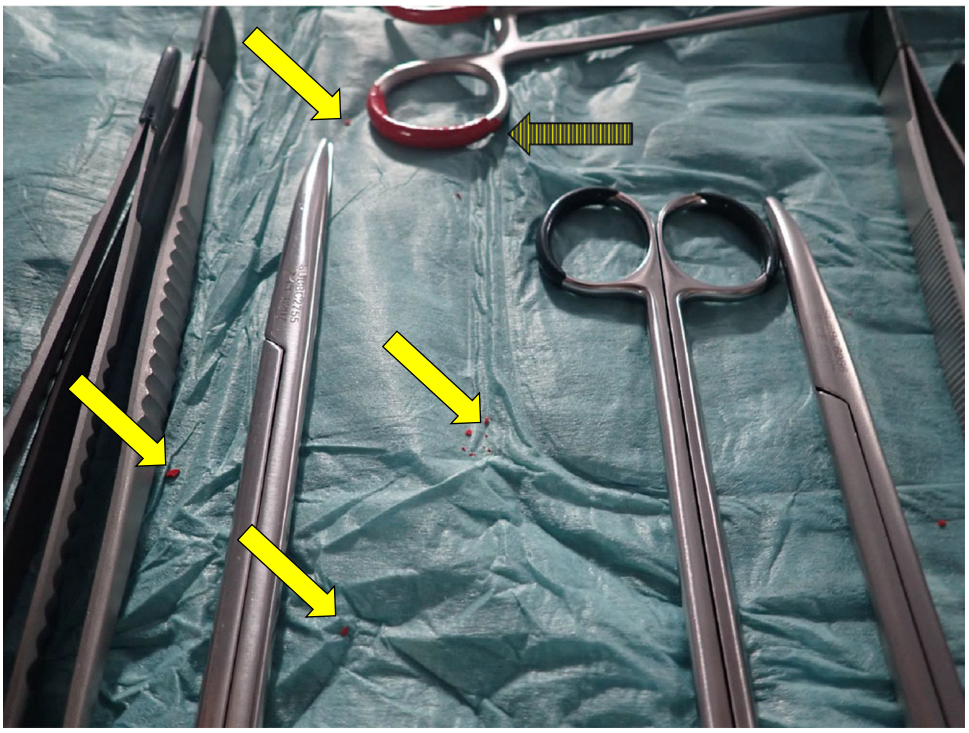

Figure 6. New, unused SI in its original packaging. The red color, which is applied as a label and safety marking, is crumbling away (black-yellow striped arrow). The crumbs are distributed over the other SI (yellow plain arrows).

quality of SI, no distinction is made between disposable and reusable products.[29,30] For field hospitals, economic and ecological aspects should play a subordinate role if they limit functionality and thereby endanger human life. Since single-use SIs have no obvious advantages and are not suitable for provisional reprocessing, field hospitals should only be equipped with reusable SI.

Sterilization vs. Disinfection

If reusable SIs are available, a provisional reprocessing can be considered. For SI that are classified as "critical MD," sterilization is required.[10,11,17] As shown in Table 1, the difference between sterilization and HLD is the extent of the sporicidal effect. In particular, the spores of *Clostridium tetani* and *C. perfringens* must be addressed in this context. *C. tetani* causes tetanus and soldiers as potential patients at military field hospitals should be vaccinated before deployment.[31] *C. perfringens* causes gas gangrene. Since the Second World War, the incidence of gas gangrene in military conflicts has decreased significantly due to better wound care and surgical techniques[32]; in recent conflicts its incidence was about 0.1% of all war-related wound infections.[33] Even with rapid detection and treatment with surgery and antibiotics, mortality is 20%-30%.[34] In addition to regular postoperative visits for secondary prevention of wound infection,[35] primary prevention through sterile SI is therefore important.

The necessary structural and technical requirements for sterilization include the number and layout of the rooms and their furnishment[36–38]; the technical building system[39]; compressed air[40]; heating, ventilation, and air conditioning (HVAC)[41]; water treatment[42,43]; and environmental aspects.[44]

Personnel requirements include the training and supervision of the staff. In Germany, for example, a sterile processing technician needs the "Fachkundelehrgang II" to reprocess and authorize the use of reprocessed MD under their own responsibility.[45] This training comprises a total of 240 hours of theoretical training, 230 hours of practical training, and 6 months of work as a trainee in an SPD before the examination.[46] Regular continued education and regular checks of the qualification status are required.[47]

The procedural requirements include, on the one hand, the actual reprocessing as a core process, as well as cleaning and disinfection,[48,49] maintenance,[50] and incident management[51] as essential support processes. The reprocessing procedure consists of several subprocesses[52]: pretreatment at the point of use; transportation, including procedures for safe transportation of hazardous materials; preparation before cleaning; cleaning; thermal disinfection or chemical disinfection; drying; inspection, maintenance, repair, and functionality testing; packaging; labeling and provision of instructions for use; and sterilization; storage.

Most of these structural, technical, personnel, and procedural requirements cannot be met if reprocessing is performed in tents or basements. But if they can be met, however, they should definitely be met. In regard to the procedural requirements, the critical process step is the manual cleaning of the SI. The reported evaluations have shown that optically clean SIs have residual protein levels below the limit of quantification after correct cleaning. However, in one of the disinfection tests (examination 24 hours after reprocessing), 4 out of 10 SIs were visually dirty. As this had nothing to do with the disinfection or the subsequent storage, the test was repeated and the cleaning process was observed. It turned out that the cleaner had not been sufficiently instructed in the standard operating procedure and was therefore unsure of his actions. This deficit could be remedied by retraining. This example emphasizes that certain requirements can be met even under field conditions and that they should definitely be met to achieve at least an HLD for the greatest possible sporicidal effect.

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Thermal vs. Chemical Reprocessing

The simplest thermal reprocessing method that can be applied is boiling of SI in 100°C hot water. This method is old and leads to an "intermediate-level disinfection" (ILD) after 15 minutes[53] and to an HLD after 30 minutes.[54,55] In the concept presented, it would be possible to switch the disinfection step from chemical to thermal without any problems. However, other MD than SI may be heat or moisture sensitive, so chemical disinfection may be a viable alternative.

When choosing a chemical disinfectant, not only the actual effectiveness but also aspects of occupational safety, material safety, and environmental protection, as well as market availability, must be taken into account. Different active ingredients are effective in general.[11]

H_2O_2 seems to be a suitable candidate for field hospitals, as it has many advantages: it requires no activation, may enhance removal of organic matter and organisms, has no disposal issues, has no odor or irritation issues, and does not coagulate blood or fix tissues to surfaces; disadvantages are cosmetic and functional material compatibility concerns for certain materials and serious eye damage with contact.[11,56] As part of this concept, H_2O_2 3% was used without any material damage to the recycled SI after 10 cycles.

Hydrogen Peroxide

The US Food and Drug Administration (FDA) lists pure H_2O_2 7.5% [Sporox™ Sterilizing & Disinfection Solution (K970230)] as a high-level disinfectant at 20°C after 30 minutes of contact time, while sterilization requires 6 hours of contact time.[57] Centers for Disease Control and Prevention (CDC) and WHO also recommend H_2O_2 6.0%-7.5% at 20°C for 30 minutes to achieve HLD.[17,18] Accelerated H_2O_2 2% [Resert™ XL HLD High Level Disinfectant (K080420, K091022)] is listed by FDA as a high-level disinfectant at 20°C after 8 minutes of contact time,[57] which is surprisingly short due to the significantly lower concentration. In practice, H_2O_2 2% was used to achieve HLD, but without specifying exposure times or if accelerated H_2O_2 was used.[2]

H_2O_2 3% is recommended for "low-level disinfection" (LLD) or ILD with an exposure time of 30 minutes, for example, in homes.[17] However, there are hints that a longer exposure time of 150 minutes has a sporicidal effect.[58] It is generally not a problem to vary the concentration of H_2O_2 or the exposure time. Further studies for the concentrations and formulations mentioned must show whether disinfection success can be ensured and whether occupational safety, material safety, and environmental protection are adversely affected. Toxicological aspects must also be investigated. H_2O_2 3% is used as a wound antiseptic,[17] but higher concentrations or other formulations could potentially cause irritation, allergic reactions, or chemical burns.[59]

Logistical Aspects

H_2O_2 3% was used in this concept because, unlike H_2O_2 6.0% or 7.5%, it is readily available on the market in Germany. H_2O_2 6.0% and 9.0% are only available as an emulsion for hairdressers. The only alternative available in Germany is H_2O_2 11.9%. Within the European Union, concentrations of 12% or more are regarded as precursors for explosives and are therefore generally not freely available for sale.[60] A immersion bath with a volume of 20 L was used for the concept presented (Figure 3, C). Plastic canisters with a volume of 5 or 10 L can be easily purchased in Germany. These canisters should be used for safe transportation and storage of the H_2O_2.[61]

Storage should be well ventilated, protected from light, and at a temperature of 15°C. It will not always be possible to comply with the temperature requirement in a field hospital. Storage of opened canisters at 45°C leads to a loss of active ingredient of about 10% within 21 days,[62] while storage at lower temperatures extends this period to up to 3 months.[63] These are sufficient time frames for the concept presented, as the field hospital is only intended to be in action for 24 hours. During this time, the H_2O_2 solution can be used continuously, as in the presented evaluation of material compatibility. For longer periods of action, the H_2O_2 solution should be replaced daily if possible,[62] but at least when the solution is visually contaminated. Further research is needed to determine how long a solution in use can achieve HLD.

The disposal of used H_2O_2 solution is regulated nationally. While the entry of H_2O_2 into wastewater and the environment should generally be avoided,[64] small quantities of no more than 3% H_2O_2 can be disposed of in wastewater in Germany without restrictions.[61] In a military context, in addition to legal requirements, it should also be borne in mind that H_2O_2 discharged into the environment may cause colour changes in flora, which could lead to detection by the enemy.

Multibarrier Approach

Prevention of surgical site infections (SSIs) and other nosocomial infections can only be achieved through a multibarrier approach.[12,65,66] The use of sterile SI is an important factor here, but it is not the only one. In the war in Ukraine, an increase in multiresistant gram-negative bacteria such as *Klebsiella pneumoniae* has been observed,[67,68] which can lead to SSI, but also to lung or urinary tract infections. These bacteria are already completely eliminated by LLD.

As with SI reprocessing, it can be assumed that many requirements for the prevention of nosocomial infections cannot be adequately met under field conditions. It must be assumed that the risk of SSI is increased because of the emergency interventions,[69–71] the injury patterns,[72–74] and the wound contamination.[75,76] Optimizing physiological and pharmacological parameters,[77] as well as sufficient antibiotic prophylaxis, is therefore necessary.

HVAC technology reduces the risk of SSI,[78,79] but air quality in tents cannot be influenced by HVAC. Mobile HVAC may solve this issue.[80] One factor that can be easily influenced, however, is poor staff hand hygiene.[81] It can be assumed that even less attention is paid to hand hygiene under the stressful conditions of a field hospital. Poor hand hygiene raises the SSI risk.[82,83] If hand disinfectant is available, even short disinfection times reduce the SSI risk,[84,85] otherwise at least hand washing should be carried out.[86]

These examples show that sterility of the SI has to be considered in a multibarrier approach. Due to the wide range of issues involved, the involvement of a specialist in hospital hygiene and antimicrobial stewardship within a field hospital is essential.

Conclusion

The reprocessing of SI as a subgroup of "critical MD" under the conditions of a field hospital in tents or basements is challenging and cannot achieve the same quality of results as an SPD. Nevertheless, it is possible to ensure a reprocessing of SI adapted to the

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circumstances with simple means. The decisive factor here is what conditions are available on site. Electricity and drinking water are necessary for the concept presented here. It is important to develop standard operating procedures and to train staff well in all process steps in order to achieve the best possible result. It is then possible to achieve HLD or, given sufficient time, even sterilization using simple chemical or thermal processes.

Supplementary material. The supplementary material for this article can be found at http://doi.org/10.1017/dmp.2025.10173.

Author contributions. UBM coordinated the evaluation for material damage, compiled all the findings, evaluated the findings, and wrote the first draft for the manuscript. EB gathered and prepared the microbiological samples and provided support during the evaluation. SF developed the overall concept for the field hospital and provided resources. EG supervised the preparation concept, provided resources, and coordinated the evaluation of the residual protein content. RMH provided resources and evaluated the microbiological samples. KL developed the preparation concept, trained the preparation staff, and supervised the preparation. GK performed the material compatibility evaluation and provided resources (Figure 6). NTM provided resources and supervised the evaluations. RMS provided resources and supervised the evaluations. RW managed the data and assisted in project management. MD planned and administered the project, coordinated all evaluation steps, analyzed all data, and revised the first draft manuscript.

All authors revised the draft and accepted the publication in its current form.

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