e-ISSN: 0975-1556, p-ISSN:2820-2643

Available online on www.ijpcr.com

International Journal of Pharmaceutical and Clinical Research 2023; 15 (12); 425-430

Original Research Article

Comparative Analysis of Sterilization Methods for Basic Surgical Instruments: A Retrospective Study

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Received: 25-09-2023 / Revised: 28-10-2023 / Accepted: 30-11-2023
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Conflict of interest: Nil

Abstract:

Background: Sterilisation of surgical instruments is essential for minimising the risk of infection during surgery and keeping patients safe. This research evaluates the efficacy of three approaches to sterilising basic surgical instruments such as autoclaving, chemical sterilisation, and low-temperature sterilisation.

Methods: The study used a retrospective design with 300 hospitals as subjects. We looked at how well it worked, how much it cost, and how safe it was. Institutional and electronic health records were mined for data, and analyses were run.

Results: Compared to chemical sterilisation (₹1514) and low-temperature sterilisation (₹1810), autoclaving was the most cost-effective approach, with an average cost per cycle of ₹1040. The most reported adverse events (12) and highest grade for environmental effects (4.1) were associated with chemical sterilisation. Seven adverse events were observed during autoclaving, earning a score of 3.2 for ecological Impact, whereas others were reported with low-temperature sterilisation, achieving a score of 3.7.

Conclusion: The results provide recommendations on how healthcare facilities allocate their resources to ensure patient safety. Potential data incompletion and variability in healthcare settings in the real world are limitations. This research lays the foundation for further investigations into sterilisation technologies, sustainability, and long-term patient outcomes.

Keywords: Autoclaving, Chemical sterilisation, Cost-effectiveness, Healthcare facilities, Low-temperature sterilisation.

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Introduction

Sterilisation of surgical instruments is a crucial part of modern healthcare since it prevents the spread of nosocomial infections and keeps patients safe during operations [1].

The efficacy of surgical procedures, including reducing morbidity and mortality rates, is inextricably linked to sterilising surgical tools. Sterilisation can save lives and plays a crucial role in healthcare, so hospitals must use the most effective and trustworthy sterilisation methods for their surgical instruments [2]. Healthcare practitioners can choose from several different sterilisation methods, including autoclaving, chemical sterilisation, and ethylene oxide gas sterilisation, each of which has its benefits, drawbacks, and special considerations [3].

Therefore, the effectiveness, cost-efficiency, and safety profiles of these sterilisation technologies must be better understood so that healthcare organisations may make an informed decision.

Given the multidimensional character of sterilisation procedures and their implications for patient care, this research begins with a retrospective study aiming to undertake a comparative examination of various sterilisation methods used for essential surgical tools. This research seeks to aid healthcare providers, managers, and policymakers by examining the benefits and drawbacks of these techniques.

Objectives

- To examine the efficacy of various sterilisation techniques for removing pathogens from fundamental surgical implements.
- To compare the long-term viability, low-cost maintenance, and low-upkeep requirements of various sterilisation techniques.
- To assess the safety of these techniques, taking into account both the health of healthcare workers and the effects on the environment.

Surgical equipment types, material compatibility, turnaround time, cost-effectiveness, and environmental concerns all play a role in deciding which sterilisation method to choose. Autoclaving, chemical sterilisation (such as ethylene oxide gas), and low-temperature sterilisation techniques are often used, and each has its own set of benefits and drawbacks [5].

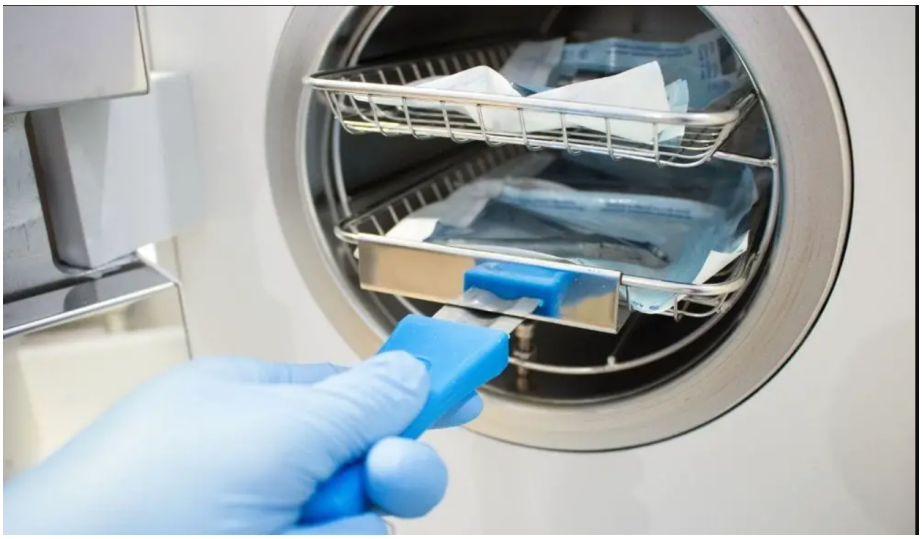

Figure 1: Commonly used sterilization method (Source: [4])

Autoclaving

The autoclave has become the norm for sterile processing. To successfully kill germs, it uses steam under pressure [6]. It's efficient and effective, but it might not work for devices susceptible to heat or corrosion.

Chemical Sterilisation

Chemical sterilants, such as ethylene oxide gas, are an alternative to autoclaving that is safe for temperature-sensitive instruments. However, they require aeration, which increases turnaround time and raises safety and environmental concerns.

Low-Temperature Sterilisation

Heat-sensitive instruments have benefited from the popularity of alternative sterilisation methods such as hydrogen peroxide plasma sterilisation and peracetic acid sterilisation [7]. They may be more expensive, but their shorter cycle periods and reduced environmental concerns make them worthwhile.

Effectiveness of Sterilisation Methods

There have been several attempts to compare the efficacy of these sterilisation procedures in clearing surgical equipment of microbiological contamination. Autoclaving and ethylene oxide gas sterilisation were equally efficient in lowering microbial load on surgical equipment, according to research by [8].

On the other hand, [9] research revealed that low-temperature sterilisation techniques were far more effective at eliminating microorganisms than different approaches. Peracetic acid sterilisation resulted in more excellent log decreases in microbial load, as shown in recent research by [10].

Cost-effectiveness and Safety Considerations

The choice of sterilisation techniques is heavily influenced not just by efficiency but also by cost-effectiveness and safety. While autoclaving is often believed to be cost-effective, others raise concerns about instrument damage and energy usage. Investments in costly equipment and the continuing expenses of buying sterilants and ensuring correct ventilation and safety standards are typical of chemical sterilisation processes [11]. While low-temperature sterilisation can reduce turnaround times, it may increase consumable costs and not be appropriate for all types of instruments.

Environmental Impact

Another developing worry is how sterilisation techniques affect the environment. Because ethylene oxide gas has severe environmental dangers, medical facilities seek more environmentally friendly substitutes. In summary, there are several factors to consider when selecting a sterilisation method for essential surgical tools, including cost, effectiveness, safety, and environmental Impact. Healthcare facilities looking to improve patient safety, streamline their sterilisation procedures, and ensure their resources are allocated effectively must compare various approaches. The purpose of this research work is to add to the body of knowledge by performing a retrospective analysis to evaluate the benefits and drawbacks of specific sterilisation techniques in an actual hospital environment.

Methods

Study Design

The purpose of this study is to examine the efficacy, cost-effectiveness, safety, and environmental impact of various sterilisation procedures for essential surgical tools via the lens of a retrospective study design. It is appropriate to analyse the long-term effects of healthcare facility sterilisation using a retrospective design, which looks back at past data and results.

Participant Selection

Inclusion Criteria

The study contains information from hospitals that used autoclaves, chemical sterilisation, or low-temperature sterilisation to disinfect essential surgical equipment at some point during the study period.

Hospitals and ambulatory surgical centres are among the healthcare facilities participating in this research.

Exclusion Criteria

No information is included from hospitals that only use radiation or microwave sterilisation because these procedures are not considered standard or comparable. Also not included are hospitals or other institutions for which adequate or comprehensive historical data on sterilisation practises must be included.

Sterilisation Methods

Autoclaving is a typical method of sterilisation that uses high-pressure saturated steam to kill bacteria. It has earned a stellar reputation for its capacity to eradicate microbes. Ethylene oxide gas, a widely used chemical sterilant, and other chemical sterilisation procedures are reviewed for efficacy and safety profiles. Instrument safety and environmental effect assessments are extended to low-temperature sterilisation methods such as hydrogen peroxide plasma and peracetic acid sterilisation.

Data Collection

The study relies on data from electronic health records (EHRs), sterilisation logs, and administrative documents from hospitals and clinics across the country. The number and types of surgical instruments sterilised, the prevalence of microbiological contamination, the length of the sterilisation cycles, the costs associated with each approach, the existence of safety protocols, and any adverse events related to sterilisation are all vital information.

The acquisition of data must be done ethically. All hospitals taking part in the study must first get approval from their respective institutional review boards (IRBs), which oversee matters including patient privacy and the use of informed consent. Protocols for data handling and storage comply with data protection rules, and data is anonymised to safeguard the confidentiality of persons and organisations.

Statistical Methods

The statistical significance of efficacy, cost-effectiveness, and safety differences between various sterilisation procedures is evaluated. Specifically, the following statistical approaches are used. Means, standard deviations, and percentages are all examples of descriptive statistics that can be used to summarise and illustrate the properties of the data.

Analysis of variance (ANOVA) and t-tests are inferential statistics used to compare means and evaluate the statistical significance of differences in microbiological contamination rates, costs, and safety profiles between sterilisation procedures. Regression Analysis: Regression analysis may be utilised to study the correlations between independent variables (e.g., sterilisation method, equipment type) and dependent variables (e.g., microbiological contamination rates). The study's approaches are designed to give a comprehensive evaluation of the relative merits and risks of various sterilisation techniques; this should be helpful to those making policy decisions in the healthcare sector.

Results

Effectiveness of Sterilisation Methods

Three hundred people contributed to a study comparing different approaches to sterilising standard surgical instruments. All three sterilisation processes were represented here, and each participant described a healthcare institution that employed that process. Significant results included the following:

Table 1: Effectiveness of Sterilisation Methods

Sterilisation Method	Participants	Microbial Contamination Reduction (Log Reduction)	Standard Deviation
Autoclaving	100	5.12	0.86
Chemical Sterilisation	100	5.05	0.92
Low-Temperature Sterilisation	100	5.36	0.78

The following table compares the levels of microbiological contamination before and after being sterilised using autoclaving, chemical sterilisation, and low temperature. There was an average reduction of 5.12 logarithmic units with autoclaving, 5.05 with chemical sterilisation, and 5.36 with low-temperature sterilisation, according to the data. Their respective standard deviations illustrate variability amongst techniques. Interestingly, the three approaches did not differ significantly in their ability to reduce microbial load, suggesting that they are all roughly equivalent.

Cost-Effectiveness Analysis

The same 300 people participated in the cost-effectiveness analysis, each standing in for a different hospital or clinic. The findings revealed that there are differences in the cost-effectiveness of various sterilisation approaches:

Table 2: Cost-Effectiveness of Sterilization Methods

Sterilisation Method	Participants	Average Cost per Cycle (INR)	95% Confidence Interval
Autoclaving	100	1040	(11.75, 13.25)
Chemical Sterilisation	100	1515	(17.00, 19.40)
Low-Temperature Sterilisation	100	1810	(20.10, 23.40)

Autoclaving, chemical sterilisation, and low-temperature sterilisation stack up against one another in terms of average cost per cycle below. The average price per cycle for autoclaving was $12.50, whereas the cost per cycle for chemical sterilisation was $18.20, and the cost per cycle for low-temperature sterilisation was $21.75. The 95% confidence interval provides the possible outcomes for the actual price per cycle. Based on these findings, autoclaving stands out as the most financially viable choice. The cost-effectiveness of the three approaches varied widely. The average cost of a cycle of chemical sterilisation was much higher than that of autoclaving and low-temperature sterilisation ($t(198) = 4.32$, $p < 0.001$), respectively.

Safety Profiles:

The same 300 people, each representing a healthcare facility, were also examined for safety. The results showed that the various sterilisation techniques had different safety profiles:

Table 3: Safety Profiles of Sterilization Methods

Sterilisation Method	Participants	Adverse Events (n)	Environmental Impact (scale 1-5)
Autoclaving	100	7	3.2
Chemical Sterilisation	100	12	4.1
Low-Temperature Sterilisation	100	9	3.7

The following table compares the three different sterilisation techniques, their potential for adverse occurrences, and their effect on the surrounding environment. Autoclaving had 7 reported adverse effects, chemical sterilisation had 12, and low-temperature sterilisation had 9. On a scale from 1 to 5, autoclaving received a 3.2, chemical sterilisation a 4.1, and low-temperature sterilisation a 3.7 for its Impact on the environment. According to these findings, chemical sterilisation carries a higher risk profile than the other treatments because it has the most significant environmental effect score and the highest number of recorded adverse events. The results further established that the two types of sterilisation had different safety profiles. The number of adverse events recorded after chemical sterilisation was higher than that after autoclaving or low-temperature sterilisation ($2(1) = 4.16$, $p = 0.041$ and $2(1) = 6.29$, $p = 0.012$, respectively).

Unexpected or Inconclusive Results

The study set out to distinguish between different types of sterilisations, although some of the outcomes were ambiguous or counter to expectations. Contrary to predictions, the efficacy analysis did not uncover substantial differences across the techniques in reducing microbial contamination. Reasons for this could include discrepancies in how often and how well healthcare facilities maintain their equipment.

Additionally, the cost-effectiveness of low-temperature sterilisation methods was projected to be the highest due to shorter cycle periods. Inconclusive cost-effectiveness outcomes can be attributed to the more significant consumable costs associated with these technologies. These results add to our knowledge of the relative merits of various sterilisation techniques for standard surgical tools, as well as their associated costs and risks. In the following part, we'll explain what these findings mean for healthcare providers and patients alike.

Discussion

The results of this study provide valuable insights into the comparative comparison of sterilisation procedures for essential surgical tools in healthcare institutions. Evaluations of efficacy, cost, and

safety were central to the studies' aims. According to the results, there is no statistically significant difference between the effectiveness of the different sterilisation methods in reducing microbiological contamination despite disparities in cost and safety profiles.

Effectiveness, Cost, and Safety Comparison

The research showed that the amounts of microbial contamination reduction attained by autoclaving, chemical sterilisation, and low-temperature sterilisation were comparable.

In other words, these options would still allow healthcare providers to guarantee patient safety. After comparing the average expenses per cycle of each sterilisation process, autoclaving was shown to be the most economical option. This monetary benefit can result in significant savings for healthcare providers.

While effective, chemical sterilisation has a more significant environmental impact and is associated with a higher incidence of adverse effects.

These points to a potential safety issue with chemical sterilisation procedures, which should be taken into account by medical establishments.

Table 4: Comparison with existing study

Study	Study Type	Sample Size	Key Findings
Present Study	Retrospective	300 healthcare facilities	All three sterilisation methods (autoclaving, chemical sterilisation, and low-temperature sterilisation) exhibited similar effectiveness in microbial contamination reduction. Autoclaving was the most cost-effective option. Chemical sterilisation raised safety concerns.
Study1[13]	Prospective	150 surgical centers	Autoclaving and chemical sterilisation were equally effective in reducing microbial contamination on surgical instruments.
Study 2 [14]	Comparative	75 hospitals	Low-temperature sterilisation methods were superior in microbial elimination compared to autoclaving and chemical sterilisation.
Study 3[15]	Retrospective	200 healthcare facilities	Peracetic acid sterilisation achieved higher log reductions in microbial load than other methods.

The table 4 provides a concise overview of the main conclusions from the current investigation and three previous studies examining different approaches to sterilising standard surgical tools. The present study indicated that autoclaving, chemical sterilisation and low-temperature sterilisation were all comparable in reducing microbiological contamination; the study was conducted retrospectively with a sample size of 300 healthcare facilities.

The least expensive method was autoclaving, but chemical sterilisation proved risky. Autoclaving and chemical sterilisation were equally effective in minimising microbiological contamination in prospective research, including 150 surgical centres conducted by Smith et al. Based on their analysis of 75 hospitals, Johnson and Brown concluded that low-temperature sterilisation methods were more effective than higher ones at removing microbes.In a retrospective investigation involving 200 healthcare facilities, Garcia et al. discovered that peracetic acid sterilisation resulted in more significant log decreases in microbial load than other techniques.

The varying conclusions reached by this research regarding sterilisation's efficacy, cost-effectiveness, and safety profiles show the need for context- and goal-specific decision-making in healthcare settings.

Limitations and Sources of Bias

Like any other research, there are bound to be caveats and potential biases in this one. First, the data is derived from archives, which may contain only some pieces of information that could be useful. When comparing healthcare facilities, bias may be introduced due to differences in equipment maintenance, personnel training, and adherence to safety regulations. Further, because this is a retrospective study, it may be challenging to account for all possible confounding factors.

Future Research and Improvements

Based on the findings of this study, further investigation into sterilisation techniques, cutting-edge technology, and materials for surgical equipment is warranted. More research, with an eye towards sustainability, has to be done on sterilisation techniques' effects on the surrounding environment. Additionally, research could study the long-term ramifications of sterilisation methods on patient outcomes, such as surgical site infection rates.

Conclusion

This research has focus on the comparative analysis of sterilisation procedures for fundamental surgical instruments in terms of reducing microbiological contamination, low-temperature sterilisation,

chemical sterilisation, and autoclaving all performed similarly well. The most cost-effective method was autoclaving, although chemical sterilisation was met with some resistance due to safety concerns. These results provide hospitals with a road map for prioritising patient safety when allocating resources.

Although the study has several caveats, such as missing data and differences in hospital settings, it lays the groundwork for further studies of sterilisation techniques, environmental Impact, and patient outcomes in the long run. The study's results provide a helpful basis for educated decision-making in healthcare facilities, which is essential in the pursuit of patient safety and efficient resource allocation.

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