

Inclusion of Cotton Fabric in a Package of Metal Instruments Retained Intrapackage Humidity after Steam Sterilization

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ABSTRACT

Aim: Packages that are wet after steam sterilization are identified as a failure in the sterilization process. The objective was to investigate whether different fabric loads and packaging materials affect temperature and humidity inside the packages after steam sterilization.

Materials and methods: Four groups of instrument packages containing either metal instruments alone or various types of fabric load (cotton, towel, or a combination) were prepared with three different packaging materials (cotton fabric, nonwoven material, or paper-film). The packages were then subjected to a full cycle steam sterilization at 121°C for 20 minutes. Percent humidity and temperature were determined immediately after removal of the package from the sterilizing chamber, and after every 15 minutes to 1 hour.

Results: The presence of any fabric inside the packages significantly increased intrapackage humidity immediately after removal from the sterilizing chamber. Intrapackage humidity dropped sharply in the packages containing metal alone or towel. The presence of cotton fabric inside the packages retained higher intrapackage humidity at every time point. The packages with metal alone had a significantly lower temperature compared with the other three groups when measured immediately. Intrapackage temperature gradually decreased in time. There was no difference in temperature between the groups from 15 minutes. The packages wrapped in cotton fabric significantly retained immediate intrapackage humidity compared with nonwoven materials or paper-film pouch.

Conclusion: Packages containing cotton fabric retained intrapackage humidity; and this may cause sterilization failure.

Clinical significance: Our data provided evidence to support that cotton fabric should not be included in the package of metal instruments for steam sterilization in routine dental instrument processing protocols.

Keywords: Autoclave, Cotton fabric, Humidity, Steam sterilization, Temperature, Wet packs.

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INTRODUCTION

Steam sterilization or autoclaving is the most common form of heat sterilization in the hospital and laboratory. Sterilization by steam is based on the principle that water is boiled in a condition above atmospheric pressure to bring the boiling point up above 100°C. Sterilization is achieved after exposure to a minimum temperature of 121°C for at least 15 minutes.

In steam sterilization, six critical principles need to be considered: (1) sterilization time, (2) temperature, (3) moisture, (4) direct steam contact, (5) air removal, and (6) drying.¹ A standard autoclave usually operates with a dry cycle in order to dry the loads after sterilization. Different types of loads, for example, metal instruments or fabrics, may have a different rate of exothermic, which can result in moisture condensation. The presence of moisture inside the loads or so called “wet packs” is not acceptable in terms of sterility because rapid recontamination readily occurs after removing the load from an autoclave.²

Condensation of steam in the sterilizing chamber of an autoclave differs per area of the autoclave. The site where to put instrument packages in the sterilization chamber is therefore crucial to minimize water condensation in the package.³ The recommendation from the Association for the Advancement of Medical Instrumentation and the Centers for Disease Control and Prevention of the USA is that the appropriate humidity for storage sterile packages should not exceed 70% relative humidity (RH) and temperature should not exceed 24°C.⁴ A lower temperature slows down the growth of microorganisms, whereas a higher humidity promotes the growth of microorganisms.⁵ Packages with high humidity or those that are wet tend to promote the attachment of

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microorganisms and make them prone to recontamination soon after removal from the sterilizing chamber.^{1,2}

Nowadays, different types of fabric are used during medical or dental treatment procedures. Most commonly, cotton fabric is used for covering the area of operation, and towel is used for wiping the hands to dry after aseptic hand washing. In some practices, these fabrics are sterilized together with metal instruments in one package. Whether fabrics together with metal instruments will alter intrapackage humidity and promote recontamination of the instruments is not known. Thus, the aim of this study is to monitor intrapackage humidity and temperature soon after removal from the sterilizing chamber. The packages contain different types of fabrics and nonfabrics or different types of packaging materials.

MATERIALS AND METHODS

The content of the packages to be tested were divided into four groups as follows:

- Group I: mouth mirror, forceps, explorer, and metal tray;
- Group II: mouth mirror, forceps, explorer, and metal tray + cotton fabric;
- Group III: mouth mirror, forceps, explorer, and metal tray + towel; and
- Group IV: mouth mirror, forceps, explorer, and metal tray + towel + cotton fabric.

The sizes of towel and cotton fabric were measured to be 27 × 27 and 73 × 91 cm, respectively.

The packaging materials used to enwrap the packages to be tested were woven sheet (two-layers of green hospital cotton sheet, 140-unit weaving/layer), nonwoven material (50 g SMMMS material, Med Con Thailand Co., Ltd, Bangkok) or paper-film pouch (70 g paper). The envelope wrapping technique was used to wrap nonwoven materials and woven materials.⁶

Each group of the four groups of packages (see above) were prepared with three different packaging materials (cotton fabric, nonwoven material, or paper-film). Each experimental group consisting of nine packages ($n = 9$) each were then subjected to full-cycle steam sterilization at 134.5°C for 60 minutes and placed on a steam ventilator (referred to the moister position). They were then cooled down for 15 minutes before removing from the chamber. Immediately after removal of the packages from the sterilizing chamber and each for 15 minutes to 1 hour, the humidity and temperature were determined by UT333 Uni-T® mini temperature and humidity meters (UT333 UNI-T®, UNI-TREND Technology China Co., Ltd, China). To accomplish this, the packages were quickly opened–closed to insert temperature and humidity meters. The measuring time was set to 15 seconds. The packages were reopened every 15 minutes to record the data. The humidity meters were

placed on a tray in group I under fabrics in groups II and III between two fabrics in group IV.

The data were statistically analyzed by one-way analysis of variance (ANOVA). Significant differences were considered at $p < 0.05$.

RESULTS

During the experimental period, room temperature (RT) was monitored and proved to be 24–26°C. Immediately after removal from the sterilizing chamber, the average intrapackage temperature of packages that contained metal instruments alone (group I) was $25.86 \pm 0.87^\circ\text{C}$ being within RT range (Fig. 1). Packages containing all types of fabrics (groups II–IV) had a higher intrapackage temperature than RT, 28.52 ± 2.13 , 27.76 ± 2.03 , and $28.91 \pm 3.56^\circ\text{C}$, respectively. Packages containing cotton fabric and towel (group IV) had the highest temperature of $28.91 \pm 3.56^\circ\text{C}$. This was significantly higher than packages with metal alone (group I). The intrapackage temperature gradually decreased in time (Fig. 1). After 30 minutes, the average intrapackage temperature of all groups was within the range of RT. There was no significant difference in temperature between the groups from 15 minutes (Fig. 1).

Immediately after removal from the sterilizing chamber a significantly higher intrapackage humidity was found in the packages containing fabrics (groups II–IV, Fig. 2). For all groups, it was apparent that intrapackage humidity gradually decreased in time. This effect was most obvious to packages containing metal alone or metal with a towel. The humidity dropped sharply and was close to 50% already after 15 minutes (Fig. 2). The presence of cotton fabric inside the packages retained intrapackage humidity to be higher than 70% at 15 minutes and close to 50% at 60 minutes (Fig. 2).

Packages that contained metal alone had a significantly higher intrapackage humidity when wrapped with cotton fabric ($87.47 \pm 10.65\%$). The same packages wrapped with nonwoven materials or paper-film pouch had an intrapackage humidity of

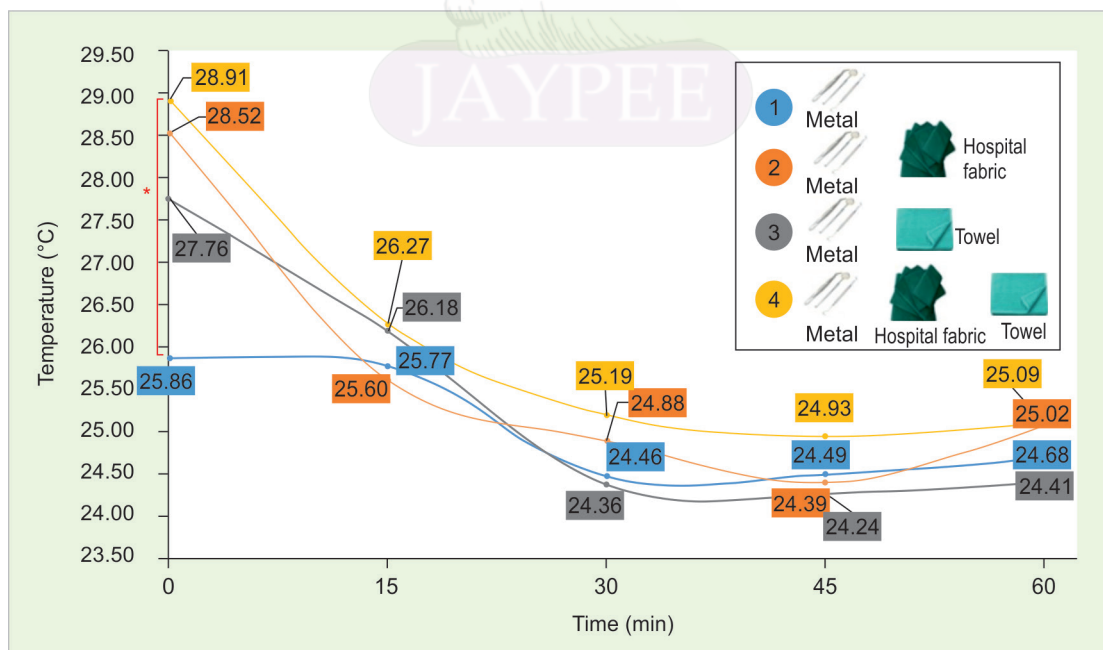


Fig. 1: Temperature in °C of four different intrapackage materials wrapped with green plain hospital cotton fabric at immediate to 60 minutes after removal from the sterilizing chamber. *Statistically significant difference with $p < 0.05$

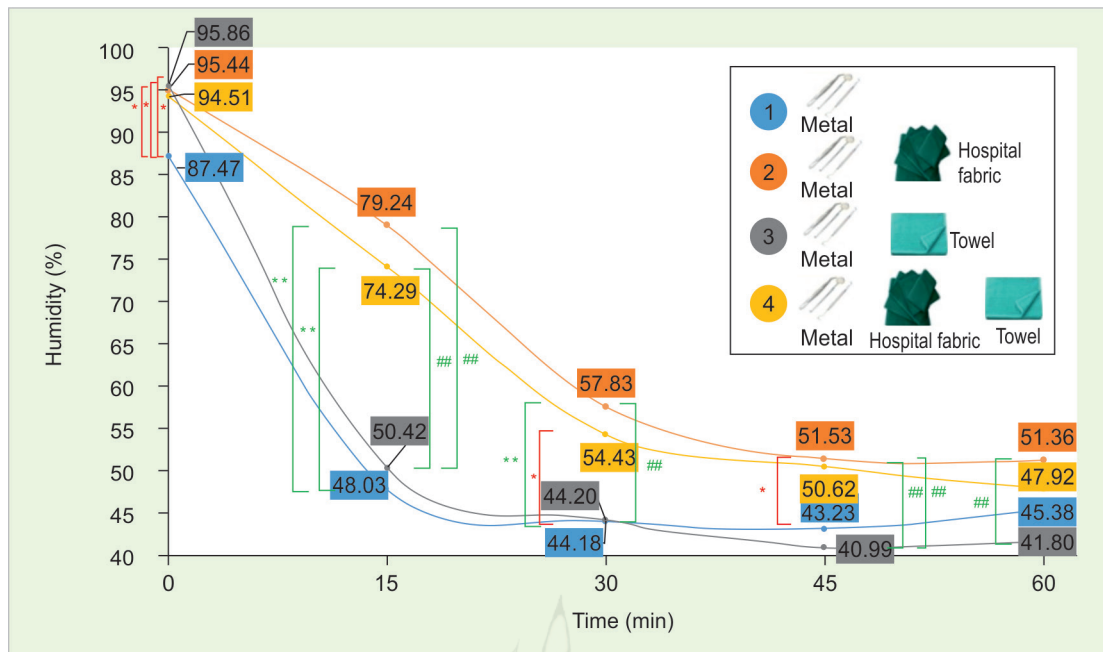


Fig. 2: Percent humidity of four different intrapackage materials wrapped within green plain hospital cotton fabric at immediate to 60 minutes after removal from the sterilizing chamber. *Statistically significant difference when compared with control group at $p < 0.05$. **Statistically significant difference when compared with control group at $p < 0.01$. ##Statistically significant difference with $p < 0.01$

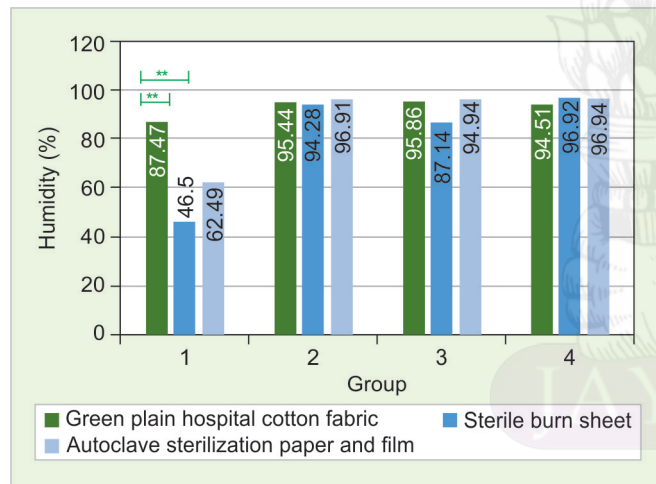


Fig. 3: Percent humidity of four different loads wrapped with three different types of wrapping materials measured immediately after removal from the sterilizing chamber. **Statistically significant difference with $p < 0.01$

46.50 ± 5.61 and $62.49 \pm 15.25\%$, respectively (Fig. 3). The packages containing metal instruments alone wrapped with cotton fabric retained intrapackage humidity compared with nonwoven materials or paper-film pouch. Regardless of the type of packaging material, the packages containing fabrics retained a humidity higher than 70% when measured immediately after their removal from the sterilizing chamber (Fig. 3).

DISCUSSION

Preparing packages of medical and dental instruments is an important step for a successful sterilization process. Despite the integrity of packaging material, the humidity of the package is a critical factor that affects the longevity of the packages when stored on the shelf. Our study demonstrated that the content

inside the package and the packaging materials significantly affect intrapackage temperature and humidity, which should be considered carefully. Differences in temperature and humidity retaining properties, durability, and permeability of the materials are important factors that may cause contamination of the sterilized instruments.

Of these factors, the humidity is critical since the higher the humidity the greater chance for contamination. The range of acceptable humidity with a lower chance of contamination was reported to be within 30–70% RH.^{3,4} A humidity higher than 70% RH has been reported to result in contamination after sterilization.^{3,4} Wet packages have the potential to attract microorganisms to enter the just-sterilized package and then recontaminate them.²

Our study revealed that the packages containing metal alone wrapped with nonwoven material or paper-film pouch had a humidity within the safety range of 30–70% RH immediately after removal from the sterilizing chamber. The humidity of packages containing any type of fabric contained moisture, as indicated by a higher intrapackage humidity. The presence of green hospital cotton fabric slowed down the rate of vaporization of moisture from the packages as demonstrated by a higher intrapackage humidity at later time points.

Thailand CSSA guidelines recommend that packages should not contain different types of instruments.⁶ Loading fabrics together with metal instruments increases density inside the package, which can lead to residual humidity. Besides, the type of textile and the size of the loaded fabric may affect the moisture content and retention. Packages containing green hospital cotton fabric demonstrated a higher intrapackage humidity than those with a towel. This was apparent immediately after removal from the sterilization machine and after 15 minutes. In this study, cotton fabric was larger in size, less in porosity, and fabricated with more threads and heavy woven than towels. Moreover, several studies have reported that cotton has the worst wicking effect, which means this fabric is hard to

let moisture evaporate.^{7,8} This property of cotton was consistent with the study of Su et al.⁹ This revealed lower diffusion and drying rate of water, as well as higher water absorption rate in higher cotton content. Nowadays, wrapping of medical devices using nonwoven materials is popular worldwide. This might be due to its suitable properties, higher vapor transmission, liquid repellency, impermeability, and good recontamination control. Some infection control experts noted that one should not use cloth as a sterilization wrapping material because it cannot resist microbe penetration. The recommended sterilization packaging materials could be just nonwoven materials, paper-film pouches, and wrapped perforated cassette.¹⁰

A wet package after steam sterilization is identified as major failure. Several factors causing wet packaging include supersaturated steam, problems with the steam valve and internal content of loads. Wet packages can also result from less drying time. After a complete cycle of steam sterilization, the packages should be left for drying and cooling for 30 minutes. During this period, the sterile packages should not be touched or placed in an area prone to contamination, such as a busy trafficking area of room.⁶ Moreover, the number of packages put in the sterilizing chamber is also critical. Too crowded loads prevent moisture removal from the sterilizing chamber and therefore affect intrapackage humidity.

CONCLUSION

Packages that contained cotton fabric together with metal instruments retained a relatively high intrapackage humidity thus representing sterilization failure. Inclusion of cotton fabric in a package of metal instruments should be avoided. Wrapping with nonwoven material and paper-film pouch promotes a better evaporation of steam and results in a lower intrapackage humidity.

CLINICAL SIGNIFICANCE

Our data provided indirect evidence to support that cotton fabric should not be included in the package of metal instruments for steam sterilization in routine dental instrument process.

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