Comparative study of current low temperature sterilization methods
(EOG, PLASMA and LTSF)

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Contents

- Low temperature sterilization portion in Japan
- Summary of study in 2005
- Technology progress from 2005 to 2012
- Feature and benefit for 3 sterilization method
- Procedure study in 2012
- Result and conclusion
Low temperature sterilization

Low temperature sterilization is applied widely as a common final re-processing process for heat-sensitive medical instruments, including hollow instruments.
Low temperature sterilization occupies 30%

Source:
EU country: Getinge internal data
JAPAN: Tokyo Metropolitan Industrial Technology Research Institute
Methods of sterilization in clinical settings

If medical equipment is heat-resistant
High-pressure steam sterilizer (Autoclave)

If medical equipment is heat-labile
As a low temperature sterilization
- Ethylene oxide gas (EOG) sterilizer
- Hydrogen peroxide gas plasma (PLASMA) sterilizer
- Low-temperature steam formaldehyde (LTSF) sterilizer

In 2005 LTSF didn’t launch in Japanese Market
A COMPARATIVE STUDY OF ETHYLENE OXIDE GAS, HYDROGEN PEROXIDE GAS PLASMA, AND LOW-TEMPERATURE STEAM FORMALDEHYDE STERILIZATION

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ABSTRACT

OBJECTIVE: To compare the efficacies of ethylene oxide gas (EOG), hydrogen peroxide gas plasma (PLASMA), and low-temperature steam formaldehyde (LTSF) sterilization methods.

METHODS: The efficacies of EOG, PLASMA, and LTSF sterilization were tested using metal and plastic plates, common medical instruments, and three process challenge devices with narrow lumens. All items were contaminated with *Bacillus stearothermophilus* spores or used a standard biological indicator.

RESULTS: EOG and LTSF demonstrated effective killing of *B. stearothermophilus* spores, with or without serum, on plates, on instruments, and in process challenge devices. PLASMA failed to adequately sterilize materials on multiple trials in several experiments, including two of three plates, two of three instruments, and all process challenge devices.

CONCLUSIONS: Our results suggest that PLASMA sterilization may be unsuccessful under certain conditions, particularly when used for items with complex shapes and narrow lumens. Alternatively, LTSF sterilization demonstrates excellent efficacy and is comparable to EOG sterilization. LTSF could potentially act as a substitute if EOG becomes unavailable due to environmental concerns (*Infect Control Hosp Epidemiol* 2005;26:486-489).
The low-temperature sterilization systems in 2005

- EOG sterilizer
- PLASMA sterilizer
  STERRAD 100
  Johnson & Johnson
- LTSF sterilizer
  GEF-449
  Getinge AB
Biological indicator (BI)
Process challenge device (PCD)

**BI**
BI possesses $10^6 >$ bacterial spores
(Bacillus steroothermophilus ATCC 7953)
SAL (sterilization assurance level) ; $10^6 >$

**PCD**
Length of hose is 150cm
Growth from biological indicators after sterilization of PCD

<table>
<thead>
<tr>
<th>Process Challenge Device</th>
<th>Positive Control</th>
<th>Sterilization System</th>
<th>EOG</th>
<th>PLASMA</th>
<th>LTSF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helix PCD* (ID, 2 mm; hose, 1.5 m)</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modified process challenge device (ID, 0.96 mm; hose, 1.5 m)</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modified process challenge device (ID, 0.96 mm; hose, 3.0 m)</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ID = internal diameter; EOG = ethylene oxide gas; PLASMA = hydrogen peroxide gas plasma; LTSF = low-temperature steam formaldehyde.

*Getinge AB, Getinge, Sweden.
Our first comparison test in 2005

1) Our results suggested that PLASMA sterilization may be unsuccessful under certain conditions, particularly when used for items with complex shapes and narrow lumens.

2) Alternatively, LTSF sterilizer demonstrated excellent efficacy and is comparable to EOG sterilizer.
The Sterilization Methods

We can choose three method from 2011

- EOG sterilizer
- PLASMA sterilizer
- LTSF sterilizer

LTSF was approved as an official “sterilization” method.
Purpose of 2012 study

This study is aimed to compare and re-evaluate the penetration efficacy of the latest low temperature sterilization technologies, and to discuss their appropriate application for hollow medical devices, such as the flexible endoscope.
Background

• Newest technology sterilizer launched in Japanese market
  – STERRAD NX
  – HS66TURBO LTSF

• Commercial Product PCDs based on EN standard instead of own making product PCDs
  • Gke plastic PCD 5 pieces
  • Gke stainless PCD 10 pieces

• Paper based Biological Indicator is not match as PLASMA. Glass fiber BI is match.
Newest Sterilization Methods

Three low-temperature sterilization systems

- EOG sterilizer (GXⅢ-6710W, Udono Limited)
- PLASMA sterilizer (STERRAD®NX™, ASP)
- LTSF sterilizer (HS66TURBO LTSF, Getinge AB)
Progress of EOG sterilization

Same technology
Ethylene oxide sterilization

- This method uses low temperature steam (30-60 °C) and ethylene oxide.
- Suitable method for sterilization of all kind of thermo-sensitive instruments
- EOG is substantially absorbed by medical materials and desorption sequences aimed for residue reduction in goods are included in the process
- Airing of sterilized goods external from the sterilizer chamber needed due to long time gas retention ability of materials
- Highly explosive and flammable gas, which requires extraordinary safety measures
- Hazardous to the environment. Combustion or catalytic degradation of gas outlet required by authorities.
- Due to high cost of the equipment and safety & environmental measures, almost completely removed from European hospitals. Method sometimes available via contract sterilization, but there is a decreasing demand because of long process times.
Progress of PLASMA sterilization

New advanced technology
SPEED (for 28 min), Penetration, Concentrate H₂O₂

STERRAD®100

STERRAD®NX
PLASMA sterilization

- This method uses hydrogen peroxide and plasma at a temperature of 50 ºC
- Suitable method for some applications. The method is not applicable for certain materials or instruments with dead-end cavities.
- No residual water (e.g. from washer/disinfector) must remain. The process requires a very deep vacuum that can not be reached with residual humidity.
- Hydrogen peroxide is absorbed by medical materials. No dedicated desorption sequences for residue reduction in sterilized goods are included in the process. Not even when the additional hydrogen peroxide booster is used.
- Traditional packaging materials can not be used. The process requires special packaging composed of only all-synthetic fabrics. If the packaging includes any cellulose fibers, it will absorb the hydrogen peroxide and the cycle fails.
- High running cost, especially due to expensive hydrogen peroxide cassettes.
- Equipment is expensive (more expensive than steam or formaldehyde sterilizers), but still not so expensive as ethylene oxide sterilizers.
STERRAD® NX™

Advanced cycle

Pressure mtorr

H₂O₂ into the concentrator

Concentrate & Vacuum

injection

Diffusion

Plasma

Air open

Plasma pre-vacuum

Second cycle

38 min
Progress of LTSF sterilization

New advanced technology
SPEED (for about 4 hour), Penetration,
High- and low-temperature sterilization in the same machine

GEF-449

HS66TURBO LTSF,
Formaldehyde sterilization

- This method uses low temperature steam (55 - 80 ºC) and formaldehyde.
- Suitable method for sterilization of all kind of thermo-sensitive instruments
- Formaldehyde is absorbed by medical materials and desorption sequences aimed for residue reduction in goods are included in the process
- No airing of sterilized goods external from the sterilizer chamber is needed
- Sterilizers are available that can be used for both low temperature formaldehyde sterilization and (as back up) for normal steam sterilization processes. This avoids the necessity of a dedicated low-temperature sterilizer
- Growing interest, because of new European standard for formaldehyde sterilization
HS66 TURBO LTSF Process Parameter (current model)

- **Pre vacuum & HCHO injection**
- **Steam pulse 2 times**
- **HCHO Injection + steam pulse 3 times**
- **Heating up 55°C**
- **Sterilization (45min) 55°C**
- **Steam pulse**
- **Air pulse**
- **Equalization, complete**

**Total Process** 4h 35min

- Conditioning 10 min
- Injection, heat up 55°C 15 min
- Sterilization 45 min
- Post pulse 2 h 55 min
- Air pulse 30 min

**Pressure Levels:**
- 101.3 Kpa (1013 mbar)
- 15.7 Kpa (157 mbar)
- 4 Kpa (40 mbar)
Process challenge device (PCD)

15 types of PCDs were used in our experiment to compare penetration efficacy of EOG, PLASMA and LTSF.

* **gke Steri-Record® PCD (gke GmbH)**
  15 types with different length and diameter of hoses being processed.
  The chamber made of plastic or steel, and the hose made of polytetrafluoroethylene.

Length of hose: 250mm ~ 4,500mm
Diameter of hose: 2mm ~ 5mm
### 15 types of PCDs

<table>
<thead>
<tr>
<th>Number</th>
<th>Chamber material</th>
<th>Hose diameter</th>
<th>Hose length</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.1</td>
<td>Stainless steel</td>
<td>2mm</td>
<td>1,500mm</td>
</tr>
<tr>
<td>No.2</td>
<td>Stainless steel</td>
<td>3mm</td>
<td>1,500mm</td>
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<tr>
<td>No.3</td>
<td>Stainless steel</td>
<td>5mm</td>
<td>1,000mm</td>
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<tr>
<td>No.4</td>
<td>Stainless steel</td>
<td>2mm</td>
<td>3,000mm</td>
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<tr>
<td>No.5</td>
<td>Stainless steel</td>
<td>4mm</td>
<td>1,500mm</td>
</tr>
<tr>
<td>No.6</td>
<td>Stainless steel</td>
<td>2mm</td>
<td>4,500mm</td>
</tr>
<tr>
<td>No.7</td>
<td>Stainless steel</td>
<td>3mm</td>
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<td>No.9</td>
<td>Stainless steel</td>
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<td>3,000mm</td>
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<tr>
<td>No.10</td>
<td>Stainless steel</td>
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<td>3,000mm</td>
</tr>
<tr>
<td>No.11</td>
<td>Plastic</td>
<td>2mm</td>
<td>250mm</td>
</tr>
<tr>
<td>No.12</td>
<td>Plastic</td>
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<td>500mm</td>
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<td>No.13</td>
<td>Plastic</td>
<td>2mm</td>
<td>750mm</td>
</tr>
<tr>
<td>No.14</td>
<td>Plastic</td>
<td>2mm</td>
<td>1,000mm</td>
</tr>
<tr>
<td>No.15</td>
<td>Plastic</td>
<td>2mm</td>
<td>1,500mm</td>
</tr>
</tbody>
</table>
Two types of spores were used for EOG and LTSF.

A paper filter containing

\[ 2.5 \times 10^6 \text{ spores of } \textit{Geobacillus stearothermophilus}. \] (ATCC 7953, Raven)

\[ 3.7 \times 10^6 \text{ spores of } \textit{Bacillus atrophaeus}. \] (ATCC 9372, Raven)

One type of spores was used for PLASMA.

A grass fiber disk containing

\[ 3.2 \times 10^6 \text{ spores of } \textit{Geobacillus stearothermophilus}. \] (ATCC 7953, CYCLESURE®, ASP)
Procedure of culture
### Result

<table>
<thead>
<tr>
<th>Sterilization methods</th>
<th>Spore</th>
<th>G.stearothermophilus</th>
<th>B.atrophaeus</th>
<th>G.stearothermophilus</th>
<th>G.stearothermophilus</th>
<th>B.atrophaeus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>EOG</td>
<td>PLASMA</td>
<td>LTSF</td>
<td></td>
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</tr>
<tr>
<td>PCD No.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.1</td>
<td>2mm × 1,500mm</td>
<td>—</td>
<td>—</td>
<td>+</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>No.2</td>
<td>3mm × 1,500mm</td>
<td>—</td>
<td>—</td>
<td>+</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>No.3</td>
<td>5mm × 1,000mm</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>No.4</td>
<td>2mm × 3,000mm</td>
<td>—</td>
<td>—</td>
<td>+</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>No.5</td>
<td>4mm × 1,500mm</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>No.6</td>
<td>2mm × 4,500mm</td>
<td>—</td>
<td>—</td>
<td>+</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>No.7</td>
<td>3mm × 3,000mm</td>
<td>—</td>
<td>—</td>
<td>+</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>No.8</td>
<td>5mm × 2,000mm</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>No.9</td>
<td>4mm × 3,000mm</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>No.10</td>
<td>5mm × 3,000mm</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>No.11</td>
<td>2mm × 250mm</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>No.12</td>
<td>2mm × 500mm</td>
<td>—</td>
<td>—</td>
<td>+</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>No.13</td>
<td>2mm × 750mm</td>
<td>—</td>
<td>—</td>
<td>+</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>No.14</td>
<td>2mm × 1,000mm</td>
<td>—</td>
<td>—</td>
<td>+</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>No.15</td>
<td>2mm × 1,500mm</td>
<td>—</td>
<td>—</td>
<td>+</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

EOG and LTSF: All 15 PCDs were negative.

PLASMA: 9 of the 15 PCDs were positive.

These positive results were gave to us when we used 2mm and 3mm diameter dead end PCDs with PLASMA sterilization.
Additional testing of PLASMA

We had the additional testing of PLASMA with 7 non–dead end (opened) PCDs.

SUS; Steel use stainless, PTFE; Polytetrafluoroethylene

### Results

<table>
<thead>
<tr>
<th>PCD</th>
<th>Raven BI</th>
<th>ASP BI</th>
</tr>
</thead>
<tbody>
<tr>
<td>material</td>
<td>size</td>
<td>G.Stearothermophilus</td>
</tr>
<tr>
<td>SUS</td>
<td>1mm × 150mm</td>
<td>—</td>
</tr>
<tr>
<td>SUS</td>
<td>1mm × 500mm</td>
<td>—</td>
</tr>
<tr>
<td>SUS</td>
<td>2mm × 400mm</td>
<td>—</td>
</tr>
<tr>
<td>PTFE</td>
<td>1mm × 350mm</td>
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</tr>
<tr>
<td>PTFE</td>
<td>1mm × 1,000mm</td>
<td>—</td>
</tr>
<tr>
<td>PTFE</td>
<td>1mm × 2,000mm</td>
<td>—</td>
</tr>
<tr>
<td>PTFE</td>
<td>1mm × 3,000mm</td>
<td>—</td>
</tr>
</tbody>
</table>

STERRAD NX could sterilize more this recommend sterilization range when we used these non–dead end (opened) PCDs.
Conclusion

This study is beneficial for the understanding of changes with current low temperature sterilization in terms of penetration efficacy, because this critically affects the final result of sterilization. Furthermore, our study can be used as a guide for selecting the appropriate low temperature sterilization method.