TWELVE

HIGH-LEVEL DISINFECTION[1]

KEY CONCEPTS you will learn in this chapter include:

- What the methods of high-level disinfection (HLD) are
- How to perform each method of high-level disinfection
- What the advantages and disadvantages of boiling and steaming are
- What the advantages and disadvantages of chemical high-level disinfectants are

BACKGROUND

Although sterilization is the safest and most effective method for the final processing of instruments, often sterilization equipment is either not available or not suitable (Rutala 1996). In these cases, HLD is the only acceptable alternative. The HLD process destroys all microorganisms (including vegetative bacteria, tuberculosis, yeasts and viruses) except some bacterial endospores.

High-level disinfection can be achieved by boiling in water, steaming (moist heat) or soaking instruments in chemical disinfectants. To be effective, all steps in performing each method must be monitored carefully.

EFFECTIVENESS OF MOIST HEAT

Essentially all vegetative forms of bacteria are killed by moist heat at temperatures of 60–75°C within 10 minutes (Salle 1973). Hepatitis B virus, which is one of the most difficult viruses to kill, is inactivated in 10 minutes when heated to 80°C (Kobayashi et al 1984; Russell, Hugo and Ayliffe 1982). In contrast, although many types of spores are killed when boiled at 99.5°C for 15 to 20 minutes (Williams and Zimmerman 1951), *Clostridium tetani* spores are quite heat-resistant and can even survive boiling for up to 90 minutes (Spaulding 1939).

The highest temperature that boiling water or low-pressure steam will reach is 100°C (212°F) at sea level. Because the boiling point of water is 1.1°C lower for each 1,000 feet in altitude, it is best to boil or steam items to be high-level disinfected for a minimum of 20 minutes. This provides a margin of safety for variations in altitudes up to 5,500 meters (18,000 ft), and at the same time eliminates the risk of infection from some, but not all, endospores.

[1] *Adapted* by: Tietjen, Cronin and McIntosh 1992.

Boiling Versus Steaming

Boiling and steaming both use moist heat to kill microorganisms. **Steaming has several distinct advantages over boiling** for the final processing of surgical gloves and other items, such as plastic cannulae and syringes. It is less destructive and, because it uses much less fuel than boiling, it is more cost-effective. For example, only about 1 liter of water is needed to steam gloves or instruments, whereas 4–5 liters are required for boiling. Also, discoloration of instruments from calcium or other heavy metals contained in some tap water does not occur, because the steam contains only pure water molecules. Finally, although boiling and steaming gloves are equally easy to do, drying boiled gloves is not practical because it is difficult to prevent contamination while they are air drying. With steaming, because they remain in the closed steamer pan, gloves are less likely to become contaminated.

The **major disadvantage of steaming** is that if the steamers available locally are small, they are only practical for use with a small number of items (e.g., one set of instruments or 15–20 pairs of surgical gloves) per tray or pan. For steaming to be effective, the bottom pan must contain enough water to continue boiling throughout the steaming process. By contrast, large boiling pots are easier to use for metal instruments and do not have to be monitored the entire time to be sure that the process is being done correctly.

Both boiling and steaming share some advantages and disadvantages over chemical high-level disinfection, which is the only other method of HLD.

Advantages

- Inexpensive procedures.
- Easily taught to healthcare workers.
- Require no special chemicals or dilutions and leave no chemical residue.
- Heat sources (boilers or rice cookers) are commonly available.

Disadvantages

- Length of processing time must be carefully measured (i.e., start timing only after steam begins to escape or water has reached a rolling boil). Once timing starts, no additional items or water can be added.
- Objects cannot be packaged prior to HLD; therefore, there is a greater chance of contamination if items are to be stored.
- Requires a fuel source that may be unreliable.

HIGH-LEVEL DISINFECTION BY BOILING

Boiling in water is an effective, practical way to high-level disinfect instruments and other items. Although boiling instruments in water for 20 minutes will kill all vegetative forms of bacteria, viruses (including HBV, HCV and HIV), yeasts and fungi, boiling will **not** kill all endospores reliably.

Instructions for HLD by Boiling

STEP 1: Decontaminate and clean all instruments and other items to be high-level disinfected.

STEP 2: If possible, completely immerse items in the water.[2] Adjust the water level so that there is at least 2.5 cm (1 inch) of water **above** the instruments. In addition, make sure all bowls and containers to be boiled are full of water. For example, empty bowls that turn bottom side up and float to the surface contain air pockets.

Remember: A gentle rolling boil is sufficient and will prevent instruments or other items from being bounced around and possibly damaged by striking other instruments or the side walls of the boiling pot.

STEP 3: Close lid over pan and bring water to a gentle, **rolling** boil. (Boiling too vigorously wastes fuel, rapidly evaporates the water and may damage delicate [or sharp] instruments or other items.)

STEP 4: Start timer. In the HLD log, note time on the clock and record the time when rolling boil begins.

STEP 5: Boil all items for **20 minutes**.

Boiling Tips

- Always boil for 20 minutes in a pot with a lid.
- Start timing when the water begins to boil.
- Metal instruments should be completely covered with water during boiling.
- Do not add anything to the pot after timing begins.

STEP 6: After boiling for 20 minutes, remove objects with previously high-level disinfected forceps. Never leave boiled instruments in water that has stopped boiling. As the water cools and steam condenses, air and dust particles are drawn down into the container and may contaminate the instruments (Perkins 1983).

STEP 7: Use instruments and other items immediately or, with high-level disinfected forceps or gloves, place objects in a high-level disinfected container with a tight-fitting cover. Once the instruments are dry, if any pooled water remains in the bottom of the container, remove the dry items and place them in another high-level disinfected container that is dry and can be tightly covered.

Protecting the Life of Instruments That Are Frequently Boiled

Lime deposits may form on metal instruments that are frequently boiled. This scale formation, caused by lime salts in the water, is difficult to avoid. By following these steps, however, the problem of lime deposits can be minimized:

[2] A study documented that the interior temperature of a plastic cannula floating on the surface of boiling water reaches a temperature of 96–98°C in less than 1 minute. Therefore, for items that float (e.g., syringes, plastic MVA cannulae or rubber items), it is not necessary that they be fully covered by the water to achieve HLD if the pot is covered with a lid (IPAS 1993).

STEP 1: Boil the water for 10 minutes at the beginning of each day before use. (This precipitates much of the lime salt in the water on to the walls of the boiling pot before objects are added.)

STEP 2: Use the same water throughout the day, adding only enough to keep the surface at least 1 inch above the instruments to be high-level disinfected. (Frequent draining and replacing the water, and boiling too vigorously, increase the risk of lime deposits on instruments.)

STEP 3: Drain and clean the boiler or pot at the end of each day to remove lime deposits.

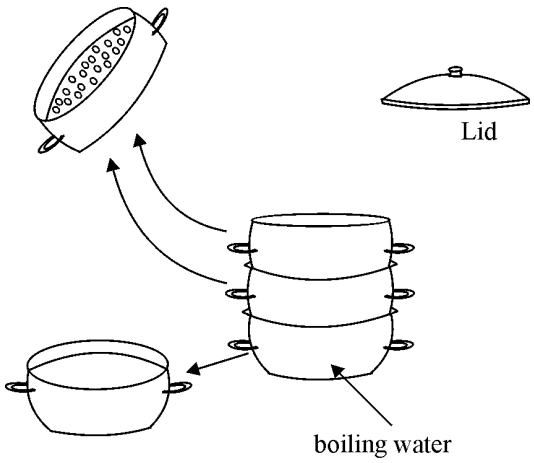
HIGH-LEVEL DISINFECTION BY STEAMING

Steaming surgical gloves has been used as the final step in processing gloves for many years in Indonesia and other parts of Southeast Asia. In 1994, a study by McIntosh et al confirmed the effectiveness of this process.

The steamer used in the study (**Figure 12-1**) consisted of:

- a bottom pan (approximately 31 cm in diameter) for boiling water;
- one, two or three circular pans with multiple 0.5 cm (diameter) holes in their bottoms to permit the passage of steam through them and water back down to the bottom pan; and
- a lid that fits on the top pan.

Figure 12-1. Steamer Used for HLD

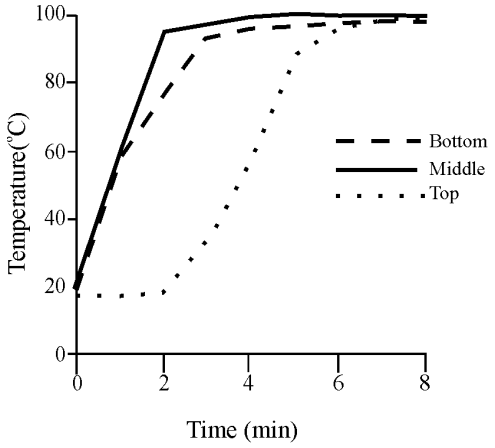


Two types of tests were conducted to determine whether surgical gloves and other items could be high-level disinfected using this process.

In the first set of experiments, a thermocouple was placed inside a glove in each of the three pans and the rate and extent of the temperature change was recorded. As shown in **Figure 12-2**, when 5–15 pairs of surgical gloves were

placed in each of the three pans, the temperature reached 96–98°C in less than 4 minutes in the bottom and middle pans and within 6 minutes in the upper pan. Thereafter, the temperature remained constant throughout the remaining 20 minutes.

Figure 12-2. Temperature Rise in Gloves as a Function of Tray Position



In the second set of experiments, batches of new surgical gloves were contaminated with *Staphylococcus epidermidis*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Candida albicans* as well as *Bacillus subtilis* (heat-sensitive) and *Bacillus stearothermophilus* (heat-resistant) endospores. Next, the gloves were placed in each of the three pans and steamed for 20 minutes. After this, the gloves were removed from the pans and incubated for 24 hours in sterile media and then were plated on blood agar. In all cases (6, 15 and 30 gloves per pan), there was no growth of any microorganisms or *B. subtilis* endospores at 24 hours. As expected, however, only a reduction in the number of *B. stearothermophilus* (heat-resistant) endospores occurred.

Instructions for HLD by Steaming

After instruments and other items have been decontaminated and thoroughly cleaned, they are ready for HLD by steaming. (See **Appendix C** for HLD of surgical gloves by steaming.)

STEP 1: Place instruments, plastic MVA cannulae and other items in one of the steamer pans with holes in its bottom (**Figure 12-1**). To make removal from the pan easier, do not overfill the pan.

STEP 2: Repeat this process until up to three steamer pans have been filled. Stack the filled steamer pans on top of a bottom pan containing water for boiling. A second empty pan without holes should be placed on the counter next to the heat source (see **Step 7**).

Remember: Be sure there is sufficient water in the bottom pan for the **entire** 20 minutes of steaming.

STEP 3: Place a lid on the top pan and bring the water to a full **rolling** boil. (When water only simmers, very little steam is formed and the temperature may not get high enough to kill microorganisms.)

STEP 4: When steam begins to come out between the pans and the lid, start the timer or note the time on a clock and record the time in the HLD log.

STEP 5: Steam items for 20 minutes.

STEP 6: Remove the top steamer pan and put the lid on the pan that was below it (the pan now on top). Gently shake excess water from the pan just removed.

STEP 7: Put the pan just removed onto the empty pan (see **Step 3**). Repeat until all pans are restacked on this empty pan and the top pan is covered with the lid. (This step allows the items to cool and dry without becoming contaminated.)

STEP 8: Allow items to air dry in the steamer pans (1 to 2 hours) before using.

STEP 9: Using a high-level disinfected forceps, transfer the dry items to a dry, high-level disinfected container[3] with a tight-fitting cover. Instruments and other items can also be stored in the stacked and covered steamer pans as long as a bottom pan (no holes) is used.

HIGH-LEVEL DISINFECTION USING CHEMICALS

Although a number of disinfectants are commercially available in most countries, four disinfectants—**chlorine**, **glutaraldehydes**, **formaldehyde** and **peroxide**—are routinely used as high-level disinfectants. (**Table 12-1** provides guidelines for preparing and using these disinfectants.) These chemicals can achieve high-level disinfection if the items being disinfected are thoroughly cleaned before immersion. A high-level disinfectant should be selected for use based on the characteristics of the items to be disinfected, the physical area (i.e., is it well ventilated) and the skills of personnel available to do the procedure.

Note: Chemical HLD of hypodermic needles and syringes is not recommended, because chemical residues, which may remain even after repeated rinsing with **boiled** water, may interfere with the action of medications being injected.

The major **advantages** and **disadvantages** of these high-level disinfectants are:

- **Chlorine solutions** are fast acting, very effective against HBV, HCV and HIV/AIDS, inexpensive and readily available (CDC 1987; WHO 1989). A major disadvantage is that concentrated chlorine solutions (>0.5%) can corrode metals; however, stainless steel and plated instruments can be safely high-level disinfected in 0.1% chlorine solution by soaking in a plastic container for up to 20 minutes. For **HLD**, the 0.1% chlorine solution should be made using **boiled** water, which has been filtered if the tap water is cloudy. Prior to soaking, the items should have been thoroughly cleaned, rinsed and dried.

[3] How to prepare a high-level disinfected container: For small containers, boil water in the covered container for 20 minutes, then pour out the water, which can be used for other purposes, replace the cover and allow container to dry. Alternatively, and for large containers, fill a plastic container with 0.5% chlorine solution and immerse the cover in chlorine solution as well. Soak both for 20 minutes. (The chlorine solution can then be transferred to another container and reused.) Rinse the cover and the inside of the container three times with boiled water and allow to air dry.

Problems from discoloration can be decreased if items are rinsed with boiled water and dried **promptly**.[4] Although chlorine solutions for HLD may deteriorate if left standing uncovered or stored in a clear (transparent) container, fresh solutions for HLD need to be made only if the solution is visibly cloudy.

Note: Using the lower chlorine concentration (0.1%) is just as effective and will extend the useful life of the instruments.

Tables 10-1 and **10-2** describe how to make 0.1% chlorine solutions from commercially available liquid bleach products and dry powders, respectively.

Note: If stored in closed, dark bottles that block light, various concentrations of commercial bleach solutions (1:100 to 1:5) do not lose their efficacy as fast as formerly thought (e.g., 50% to 97% potency at 30 days) with higher concentrations being more stable (Rutala et al 1998).

- **Formaldehyde** (8%), which is inexpensive and readily available, is an effective high-level disinfectant (HLD) but, as mentioned previously, the vapors are very irritating and it is classified as a potential carcinogen. Care must be taken to protect both staff and patients from the fumes when mixing and using formaldehyde solutions. **Do not dilute with chlorinated water as a dangerous gas (bis-chloromethyl-ether) can be produced.** Staff should wear gloves to avoid skin contact, protect eyes from splashes, limit exposure time and use these solutions only in a well-ventilated area.
- **Glutaraldehydes** are less irritating than formaldehyde, but staff and clients still need to be protected from the fumes when mixing and using these solutions. Staff should wear gloves and protective eyewear to avoid skin contact, protect eyes from splashes, limit exposure time and use only in a well-ventilated area.

Remember: Because both glutaraldehydes and formaldehyde (formalin) solutions leave a residue, instruments must be rinsed thoroughly with **boiled** water **three** times after chemical HLD to remove any residue and prevent skin irritation.

- **Hydrogen Peroxide** (H_2O_2), which must be diluted to a 6% solution, often is available locally and is less expensive than other chemical disinfectants. The 3% H_2O_2 solutions used as antiseptics, however, should not be used as a disinfectant. The major disadvantage of peroxide is that it is highly corrosive and should not be used to disinfect copper, aluminum, zinc or brass. Also, because it loses potency rapidly when exposed to heat and light, it should be stored in a cool, dark place. WHO does not recommend using H_2O_2 in hot (tropical) climates because of its instability in the presence of heat and light (WHO 1989).

Advantages and disadvantages of each of these chemical disinfectants are summarized in **Appendix F**.

[4] Discoloration of metal items, which occurs when calcium (not sodium) hypochlorite powders are used, often is confused with corrosion (rusting). Wiping discolored items with a cloth soaked with vinegar (dilute acetic acid) will quickly remove discoloration.

Alcohols and Iodophors

Although alcohols and iodophors are inexpensive and readily available, they are no longer classified as high-level disinfectants. Alcohols do not kill some viruses and are not sporicidal, and *Pseudomonas* species have been shown to multiply in iodophors (Favero 1985; Rutala 1993). These chemicals should be used only when the high-level disinfectants listed above are not available or appropriate.

Key Steps in Chemical High-Level Disinfection

- Decontaminate instruments and other items that may have been contaminated with blood and body fluids, and thoroughly clean and dry them before placing them in the disinfectant solution.
- Completely immerse all items in the high-level disinfectant.
- Soak for 20 minutes.
- Remove items using high-level disinfected or sterile forceps or gloves.
- Rinse well with **boiled** and filtered (if necessary) water three times and air dry.
- Use promptly or store in a dry, high-level disinfected, covered container.

Adapted from: Tietjen and McIntosh 1989.

Storage of Disinfectants

- Chemical disinfectants should be stored in a cool, dark area.
- Never store chemicals in direct sunlight or in excessive heat (e.g., upper shelves in a tin-roofed building).

Disposal of Used Chemical Containers

- **Glass containers** may be washed with soap, rinsed, dried and reused. Alternatively, thoroughly rinse glass containers (at least two times) with water and dispose of by burying.[5]
- **Plastic containers** used for toxic substances such as glutaraldehydes or formaldehyde should be rinsed (at least three times) with water and disposed of by burning or burying.

Disposal of Used Chemicals

Carefully pour wastes down a utility sink drain or into a flushable toilet and rinse or flush with water. Liquid wastes can also be poured into a latrine. **Avoid splashing.** Rinse the toilet or sink carefully and thoroughly with water to remove residual wastes.

[5] To further prevent them from being misused, put a hole in each container before disposal so that water or other liquids cannot be carried in it.

Table 12-1. Preparing and Using Chemical Disinfectants

CHEMICALS FOR STERILIZATION OR HIGH-LEVEL DISINFECTION

Disinfectant (common solution or brand)	Effective Concentration	How to Dilute	Skin Irritant	Eye Irritant	Respiratory Irritant	Corrosive	Leaves Residue	Time Needed for HLD	Time Needed for Sterilization	Activated Shelf Life[a]
Chlorine	0.1%	Dilution procedures vary[b]	Yes (with prolonged contact)	Yes	Yes	Yes[c]	Yes	20 minutes	Do not use	Change every 14 days, sooner if cloudy.
Formaldehyde (35–40%)	8%	1 part 35–40% solution to 4 parts boiled water	Yes	Yes	Yes	No	Yes	20 minutes	24 hours	Change every 14 days, sooner if cloudy.
Glutaraldehyde (Cidex®)	Varies (2–4%)	Add activator	Yes	Yes (vapors)	Yes	No	Yes	20 minutes at 25°C[d]	10 hours for Cidex®	Change every 14–28 days; sooner if cloudy.
Hydrogen Peroxide (30%)	6%	1 part 30% solution to 4 parts boiled water	Yes	Yes	No	Yes	No	20 minutes	Do not use	Change daily; sooner if cloudy.
CHEMICALS FOR DISINFECTION (alcohols and iodophors are not high-level disinfectants)										
Alcohol (ethyl or isopropyl)	60–90%	Use full strength	Yes (can dry skin)	Yes	No	No	No	Do not use	Do not use	If container (bottle) kept closed, use until empty.
Iodophors (10% povidone-iodine) (PVI)	Approximately 2.5%	1 part 10% PVI to 3 parts water	No	Yes	No	Yes	Yes	Do not use	Do not use	If container (bottle) kept closed, use until empty.

[a] All chemical disinfectants are heat- and light-sensitive and should be stored away from direct sunlight and in a cool place (<40°C).
[b] See **Tables 10-1 and 10-2** for instructions on preparing chlorine solutions.
[c] Only corrosive with prolonged (>20 minutes) contact at concentrations >0.5% if not rinsed immediately with boiled water.
[d] Different commercial preparations of Cidex and other glutaraldehydes are effective at lower temperatures (20°C) and for longer activated shelf life. **Always** check manufacturers' instructions.

Adapted from: Rutala 1996.

Products That Should Not Be Used as Disinfectants

Many antiseptic solutions are used incorrectly as disinfectants. Although antiseptics (sometimes called "skin disinfectants") are adequate for cleansing skin before surgical procedures, they are not appropriate for disinfecting surgical instruments and gloves. **They do not reliably destroy bacteria, viruses or endospores.** For example, Savlon (chlorhexidine gluconate with or without cetrimide), which is readily available worldwide, is often mistakenly used as a disinfectant.

Antiseptics that should not be used as disinfectants are:

- Acridine derivatives (e.g., gentian or crystal violet)
- Cetrimide (e.g., Cetavlon®)
- Chlorhexidine gluconate and cetrimide in various concentrations (e.g., Savlon)
- Chlorhexidine gluconate (e.g., Hibiscrub®, Hibitane®)
- Chlorinated lime and boric acid (e.g., Eusol®)
- Chloroxylenol in alcohol (e.g., Dettol®)
- Hexachlorophene (e.g., pHisoHex®)
- Mercury compounds

Mercury solutions (such as mercury laurel), although low-level disinfectants, **cause birth defects** and are too toxic to use as either disinfectants or antiseptics (Block 1991). (See **Appendix B** for details.)

Other products frequently used to disinfect equipment are 1–2% phenol (e.g., Phenol®), 5% carbolic acid (Lysol®) and benzalkonium chloride, a quaternary ammonium compound (Zephiran®). These are low-level disinfectants and should only be used to decontaminate environmental surfaces (e.g., floors or walls).

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