Distributed surgical instrument sterilization using
SOLAR POWERED AUTOCLAVES
in low resource settings

THE NEED FOR SURGICAL CARE

Global surgeries: As the world's burden of surgical diseases increases, so does the gap between access to life saving and disability preventing surgical care, both between and within countries. As seen in Figure 1, less than 5% of the world's surgical procedures are performed in countries ranked in the lowest third of per capita health expenditure. Barriers to the delivery of safe and timely surgery include deficiencies in capacity and quality. Surgery is often the only solution to prevent disabilities and death from conditions resulting from road traffic accidents, falls, burns, disasters, domestic violence, pregnancy related complications, infections and congenital defects. The WHO estimates that 500,000 women die annually from complications in pregnancy that can be easily solved with simple surgical intervention at the primary health clinic point of care. Pregnancy complications and other surgical diseases seen in Figure 2 account for 11% of the Global Disease Burden.

The surgical care gap between developing and developed countries could be substantially reduced through integrated strategies including appropriate medical equipment design for surgical procedures in low-infrastructure areas.

The WHO states that most of the surgical care required to reduce the global disease burden can be given at the primary level of health care, which for most of the world, is provided by rural clinics. Rural clinics in developing countries provide primary care for 3 billion people worldwide, but more than half of them do not have access to electricity. Additionally, although they lack the proper equipment, nurses at these clinics are faced with the decision to compromise patient safety by attempting to provide care. When minor wound injuries are left untreated, patients are inappropriately treated by the primary care clinics, infections can rapidly spread. Every year there are 50-60 million people in the developing world suffering from wound injuries. Even in areas the autoclave at the hospital will not be available.

The solar autoclave uses a parabolic solar concentrator and a small boiler to collect solar energy to generate steam that is transferred to an insulated pressure vessel and an electronic sterilization indicator (Figure 3). Proof of concept experimentation was done to ensure that the 250ml boiler and parabolic concentrator generated the appropriate amount of steam for a 5L insulated pressure vessel. Early testing showed the system will need two concentrators for this amount of steam. A sterilization indicator is measures temperature and activates an LED when the appropriate measures for sterilization are reached. Advantages of this solar autoclave design include: (1) decoupled solar concentrator and pressure vessel to reduce volatility in solar collection (2) ability to scale the system size with additional solar concentrators (3) modular electronics to measure temperature, pressure, sunlight and external energy (4) design for manufacturing and flat pack shipping.

<table>
<thead>
<tr>
<th>DEVELOPMENT</th>
<th>SOLAR OVEN I</th>
<th>SOLAR OVEN II</th>
<th>SOLARCLAVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUBASSEMBLIES</td>
<td>8 PARTS</td>
<td>5 PARTS</td>
<td>8 PARTS</td>
</tr>
<tr>
<td>SUPPLY CHAIN COMPLEXITY</td>
<td>100% LOCAL MATERIALS</td>
<td>90% LOCAL MATERIALS</td>
<td>90% LOCAL MATERIALS; 100% LOCAL REPLACEABLE PARTS</td>
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<td>ASSEMBLY TIME</td>
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<td>1 DAY</td>
<td>3 DAYS</td>
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<tr>
<td>MANUFACTURE TRAINING</td>
<td>7 DAYS</td>
<td>8 DAYS</td>
<td>10 DAYS</td>
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<tr>
<td>USER TRAINING</td>
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<td>3 HOURS</td>
<td>1 DAY</td>
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<tr>
<td>VOLUME</td>
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<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td>COST</td>
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<td>~$300</td>
<td>~$400</td>
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We describe a new method for medical instrument sterilization using solar energy instead of conventional fuels, the Solarclave. The technology allows for the safe and reliable steam sterilization of surgical instruments in clinics without electricity, such as those found in the developing world. An autoclave is defined as a vessel capable of holding high pressure steam at 15psi and insulation to maintain the internal temperature at 121⁰C. Our solar autoclave uses a parabolic solar concentrator and a small boiler to collect solar energy to generate steam that is transferred to an insulated pressure vessel and an electronic sterilization indicator (Figure 3). Proof of concept experimentation was done to ensure that the 250ml boiler and parabolic concentrator generated the appropriate amount of steam for a 5L insulated pressure vessel. Early testing showed the system will need two concentrators for this amount of steam. A sterilization indicator is measures temperature and activates an LED when the appropriate measures for sterilization are reached. Advantages of this solar autoclave design include: (1) decoupled solar concentrator and pressure vessel to reduce volatility in solar collection (2) ability to scale the system size with additional solar concentrators (3) modular electronics to measure temperature, pressure, sunlight and external energy (4) design for manufacturing and flat pack shipping.

REFERENCES


COLLABORATION

The Solarclave research team has partnerships with Universities, NGOs, medical professionals and engineers for the device design, testing and implementation. We welcome the opportunity to collaborate with other medical care providers delivering surgical care in resource poor settings and practitioners developing solutions to surgical needs in developing countries.

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GLOBAL SURGEON DENS PERFORMANCE

GLOBAL DISEASE BURDEN

AN APPROPRIATE AND AFFORDABLE SOLUTION

Solarclave System Design

SOLARCLAVE SYSTEM DESIGN

Solar Concentrator

Medical Instrument Pressurization Unit

Steam Generator

Sterilization Indicator

Figure 2

Solarclave TM

Solar Autoclave

Boiling water

Centralized Hospital

Tabletop Autoclave

Effectiveness

Cost

Figure 4

Figure 4 compares current options for sterilization against the cost and effectiveness of those efforts. Moving from the left side of the compass, boiling water to clean instruments is not endorsed by the WHO as a reliable method of sterilization. It does not kill 100% of the microbes present on surgical devices. Chemical sterilants are another option for instrument sterilization. However, this process is complex and which create a high probability for user error. Equipment used in the procedure can rapidly spread. Every year there are 50-60 million people in the developing world suffering from wound injuries. Even in areas the autoclave at the hospital will not be available. Tabletop autoclaves are another option, but are prohibitively expensive and most require a source of electricity for power. The alternative source of power is a propane stove, however, according to the logistics supervisor of Doctors Without Borders, the supply chain for these items is limited. Our solution: a solar powered autoclave. The sterilization cycle for the solar autoclave is the same as a tabletop autoclave, but is powered using renewable energy, a free and abundant resource.

Effectiveness

Cost