Medical Aid International
Supporting Healthcare in Low Resource Environments

OPERATING ROOM EQUIPMENT LEVELS IN LMICs

MedAid Academy

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Est. 2001
MedAid International

Significant investment is required to improve the standard of equipment available in operating rooms across LMICs.

Particular areas of concern are:

- Lack of functioning autoclaves.
- Lack of soda lime use and monitoring for closed circuit anaesthetic machines.
- Poor carbon dioxide and anaesthetic agent monitoring (with lack of child and neonate sizing).
- Poor quality operating tables (electric, with exposed metal and lack of accessories).
- Lack of suction machines (almost all of which are without battery backups).
- Lack of battery backups in operating room lights, as well as significant position drift.

EXECUTIVE SUMMARY

A broad range of healthcare facilities across 7 LMICs were surveyed, with a particular focus on Africa. In total 75 operating rooms were surveyed from 30 unique healthcare facilities. The majority of hospitals surveyed had 200+ beds, with the plurality having 2 operating rooms, capturing the most likely conditions for operations in LMICs.

72% of autoclaves surveyed were fully functioning. However, when considering if a facility has one or more functioning autoclave on site, 10% did not have a working autoclave. In terms of front loading capabilities, 56% of main autoclaves were front loading, with 77% of healthcare facilities having access to a front loading autoclave. 90% met the sterilisation benchmark standard.

Approximately 53% of operations were carried out under general anaesthetic, 30% under spinal and 18% under regional/local anaesthetic. The majority used closed anaesthetic machines, although 30% did not use (or never replaced) the soda lime. Just 22% replaced that soda lime weekly or monthly (a key concern). Medical gas availability had oxygen universally available. Halothane was widely used, with significant use of Isoflurane and lower use of Sevoflurane. 57% met the benchmark standard for soda lime replacement and 49% for also having carbon dioxide and anaesthetic agent monitoring (vital for closed circuit machines). Overall, 49% of operating rooms met the benchmark standards, but only 10% of closed circuit machines were safe.

There was a huge range of availability of patient monitoring solutions with pulse oximetry being the most common (92%) and anaesthetic agent monitoring the least (36%). Blood pressure monitoring and ECG were broadly available, whilst carbon dioxide and anaesthetic monitoring were much less frequently used. Adult accessories were common, with child and neonate less so. 84% met the benchmark standards for blood pressure and pulse oximetry, but just 40% also had the correct variety of accessory sizes.

In terms of operating tables, 21% had exposed metal, putting patients at risk of diathermy/ESU burns. 85% of tables were height adjustable and 75% could go into the Trendelenburg position, with 15% being able to do neither. Accessory availability was very poor, with 27% of operating tables having no accessories. 61% of operating tables were manual, but only 10% of operating tables met all 4 benchmark standards.

Suction was only fully available in 56% of operating rooms, with 5% having no access to suction at all. Only 4 of the 75 operating rooms had a suction machine with a battery backup. This meant that a tiny 4% of operating rooms passed the benchmark standards for suction.

Oxygen was available in every operating room – a real positive – with it mainly being supplied through oxygen cylinders. The use of a pipeline was more common than might be expected, with almost half of facilities also using this method of delivery. Given every operating room had access to an oxygen supply, all 75 operating rooms met our benchmark standards.

Lighting had some well and poorly performing aspects. Almost all were ceiling mounted (88%) and most had all bulbs working (72%). Many suffered from drift (32%) and almost none (18%) had a battery backup. No operating room lights met the benchmark standards due to a combination of the latter 2 factors.

When considering our benchmark standards for each section, and looking at the proportion of healthcare facilities that passed each standard the results are, in descending order:

- Oxygen – 100% (due to Covid highlighting the need for oxygen).
- Sterilisation – 90% (due to lack of functioning autoclaves).
- Anaesthetics – 49% (mainly due to lack of soda lime replacement and poor monitoring).
- Patient Monitoring – 40% (mainly due to lack of child and neonate sized accessories).
- Operating Tables – 10% (due to a lack of necessary accessories, and electric operation).
- Suction – 4% (due to lack of battery backups).
- Lighting – 0% (due to a lack of battery backups).

Out of all 75 operating rooms, not a single one can be considered safe, i.e. meeting all our benchmark standards across all sections.

It should also be noted that this, most likely, represents a best case scenario for LMICs. Healthcare facilities that we have worked with (and provided a place on our Biomedical Engineering Course) are probably more engaged, and better equipped than most.

If we had chosen exclusively rural locations, where we had not sent any equipment or trained any Biomedical Engineers, the results would almost certainly have been worse.

TABLE OF CONTENTS

1 – INTRODUCTION

1.1 – Introduction from the Chief Executive Officer, Tim Beacon

Those of us involved in delivering surgical care to patients in the LMIC environment will be only too aware of how, in the very vast majority of locations globally, the standard of equipment falls way below anything that is acceptable. This directly impacts patient care and makes the medical team's job even harder than it already is. To be constantly faced with poor equipment in difficult clinical circumstances is demoralising at the best of times; and of course, the opposite is true – appropriate, well designed equipment and support is a real boost to all concerned, and directly impacts patient care.

There are many reasons for this unacceptable situation: it may be poor and ill-informed donations, despite the best of intentions; substandard procurement decisions, challenging logistics, lack of budget or someone to bring all the different stakeholders together (to oversee and manage the whole process).

As a Social Enterprise, ever since we started work twenty years ago, it has been our mission to try and change this. Our aim is to enable patients, and the medical staff who treat them, to have the best and most appropriate resources possible.

Whilst all of us who work in the demanding environments know the surgical facilities are generally very inadequate, we, quite rightly, live in an evidence based world. It is against this background that we contacted our biomedical engineering training graduates, who, as part of their programme, complete a detailed module on operating rooms, and asked them a series of questions concerning their facilities.

This report is the outcome of that study, and forms part of our ongoing research into equipment levels and healthcare standards in LMICs. It proves what we already know: how unacceptably poor and dangerous the standards are at many sites. That is why we have already created an all-inclusive, easy to transport operating room package that delivers on all the issues identified, and that can be in use in two hours (see Appendix A).

It is the sincere hope of myself and my team at Medical Aid International that the information in this report will act as a catalyst for improved surgical facilities and, by default, surgical care across LMICs.

Tim Beacon – Chief Executive Officer, Medical Aid International

1.2 – Introduction from the Medical Advisor, Dr Roy Miller

As Medical Advisor to Medical Aid International, this report is a welcome addition to the limited information available about the state of equipment used in many healthcare facilities in less well-resourced countries.

During my time working as an anaesthetist in Malawi, I was always impressed by the versatility of the anaesthetists. I worked mostly with clinical officers, who used the limited resources they had to provide safe anaesthesia for the many patients who needed surgery.

There were, however, a number of occasions when the lack of appropriate equipment did impact on patient safety, both because of the limits of what was provided, and also because of a deficit of the skills needed to repair broken equipment.

With Medical Aid International's tailored packages of equipment, designed to be appropriate for the clinical settings they are sent to, there is the potential to tackle the deficit of safe equipment demonstrated in this report. Additionally, through our Online Biomedical Engineering Programme, we have started to tackle the shortfall of skills needed for effective equipment repairs.

In summary, we hope that the results of this survey will provide a catalyst for change to empower the many dedicated clinical staff facing the challenges highlighted in this report.

Dr Roy Miller MB BS BSc FRCA – Medical Advisor, Medical Aid International

1.3 – What is the Medical Aid International Online Biomedical Engineering Programme?

With our many years' experience providing and installing equipment in LMICs, and also training Biomedical Engineers on residential programmes, we knew how talented the general 'fixers' were in most hospitals. They had immense enthusiasm, and when we taught them informally, they thrived on the opportunity to learn and to help us work. They also rarely had any tools, which really inhibited them.

Against this background, recognising that residential training programmes were very expensive and we would never be able to reach everyone, we created an online Biomedical Engineering Programme aimed at the people described. This recognised the power of the internet and its availability in LMICs.

The basic principles of the course are:

1. The students all receive a professional tool kit.
2. They receive textbooks and a USB flash drive of service manuals.
3. They undertake an online course, over 15 units with 72 videos.
4. There are 300 multiple choice questions throughout the 15 units. They can be taken as many times as required, but the question and answer orders change each time, ensuring robust learning.
5. The course is City & Guilds Assured, a globally recognised awarding body.
6. The course is available in French and English.
7. It includes LMIC based first aid and train the trainer elements.

More can be seen on or MedAid Academy website, where there is also a data analysis report on the first 50 students to complete the course.

> The fact that all this data is collected by people who have completed our Biomedical Engineering training programme means they are informed and know what they are looking for.
>
> An additional advantage of the course is this immense source of data collection personnel who have an established relationship with Medical Aid International.

1.4 – Report Objectives

This report seeks to investigate a variety of topics. These include:

- Size, Location and Type of Healthcare Facilities in LMICs
- Sterilisation Practices at Facilities in LMICs
- Anaesthetic Practices at Facilities in LMICs
- Patient Monitoring at Facilities in LMICs
- Operating Table Conditions at Facilities in LMICs
- Suction at Facilities in LMICs
- Oxygen Supply at Facilities in LMICs
- Operating Lights at Facilities in LMICs

1.5 – Report Methodology

The survey was broken into 2 separate sections: 1 for sections 2.1–2.7, and 1 for section 2.8.

For sections 2.1–2.7, 33 participants responded to the survey, of which 30 responses were from unique institutions. In deciding which response to accept from each institution, the first response was always taken (as this likely represents the most enthusiastic students, who are more likely to provide accurate information). Within the responses, data was collected on 75 operating rooms (unless otherwise stated).

For section 2.8, 29 participants responded to the survey, of which 27 responses were from unique institutions. In deciding which response to accept from each institution, the first response was always taken (as this likely represents the most enthusiastic students, who are more likely to provide accurate information). Within the responses, data was collected on 68 operating rooms.

Data from both surveys was matched up as students used the same email address when responding to both surveys.

In each operating room section of the report, we have developed a series of benchmark standards that reflect standards we would expect any safe operating room to meet. These are set out within each section.

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2 – SUMMARISED DATA ANALYSIS FINDINGS

2.1 – Size, Location and Type of Healthcare Facilities in LMICs

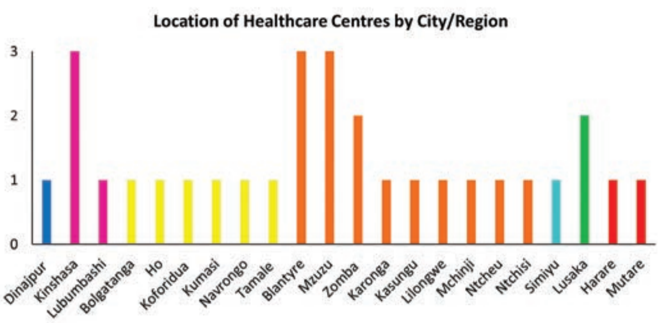


Figure 1. Count of responses categorised by the city of their healthcare facility. Locations in Bangladesh in blue, DRC in pink, Ghana in yellow, Malawi in orange, Tanzania in teal, Zambia in green and Zimbabwe in red.

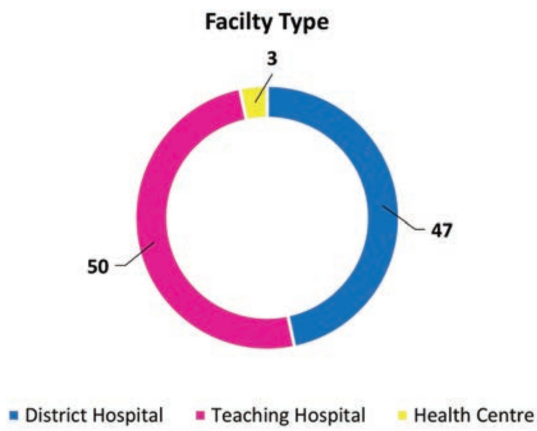


Figure 2. Facility type for each response as a proportion of total responses (in %).

- There is a broad geographic distribution of responses across 7 LMICs.
- There were 30 unique healthcare facility responses in total.
- Half the healthcare facilities surveyed were teaching hospitals, the other half were almost all district hospitals. Only 1 respondent categorised their facility as a health centre.

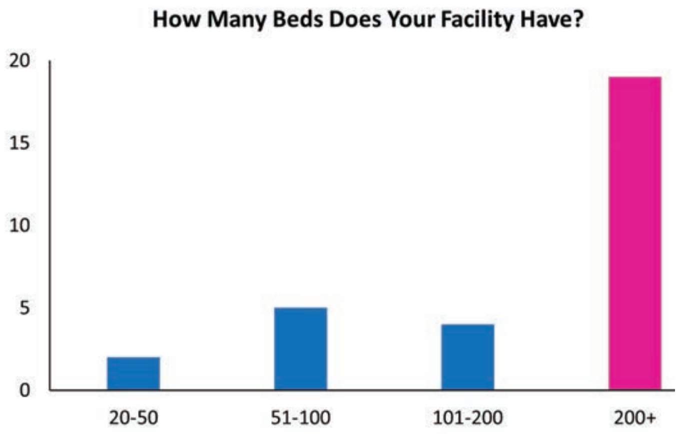


Figure 3. Count of the number of beds in each healthcare facility surveyed.

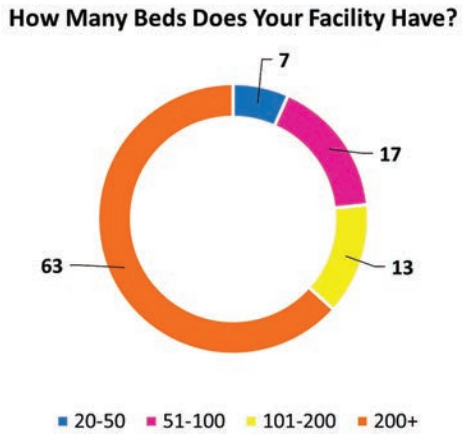


Figure 4. Proportion of healthcare facilities with each number range of beds (in %).

- The majority of survey responses came from facilities with greater than 200 beds.
- Therefore, the data should be representative of the majority of operations carried out in LMICs (most of which will happen at large facilities).
- Small facilities, with 20-50 beds, made up a small proportion (7%) of the healthcare facilities surveyed.

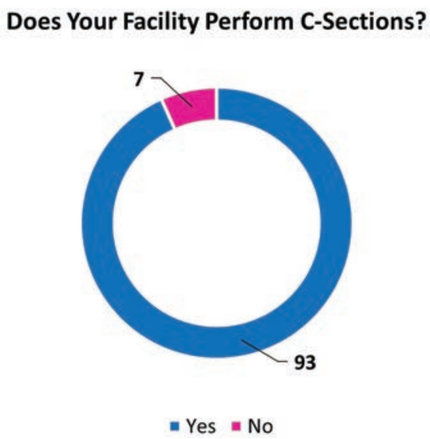


Figure 5. Proportion of facilities that perform C-section Operations (in %).

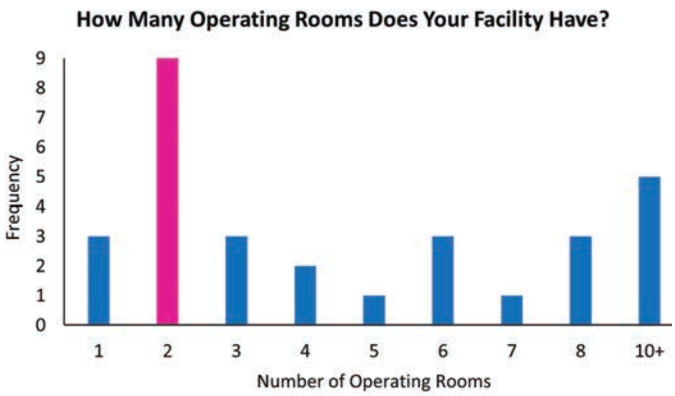


Figure 6. Count of the number of operating rooms at each facility.

- “Does your facility perform C-sections?” used as a secondary check metric to determine hospital size. It is likely that the smaller the clinic, the less likely they are to perform C-sections.
- This data lines up well with the hospital size data, with 7% of hospitals having 20-50 beds, and 7% not performing C-sections.
- It should be noted this 7%, which don’t perform C-sections, represents 2 facilities: one 51-100 bed, and one greater than 200 bed facility.
- The largest proportion (30%) of facilities surveyed had 2 operating rooms, with the next most common, over 10+, making up 17% of the total.

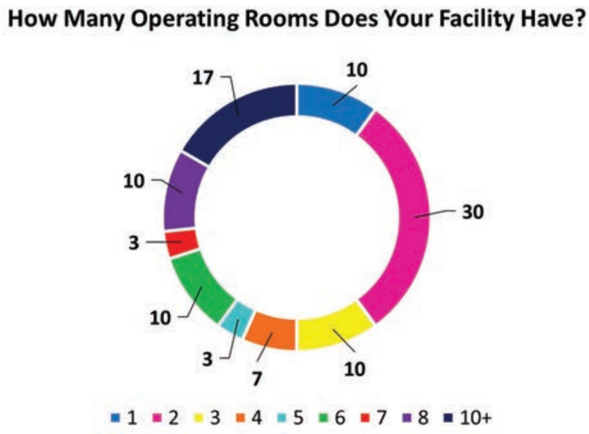


Figure 7. Proportion of facilities with the corresponding number of operating rooms (in %).

- Again, it can be seen that having 2 operating rooms (in pink) was the most common for a healthcare facility, followed by having over 10 operating rooms (in dark blue).

2.2 – Sterilisation Practices at Facilities in LMICs

Autoclaves – An Overview

Working and appropriate autoclaves are a prerequisite for any healthcare facility. Without a properly functioning autoclave (and there should be more than one for back up), no healthcare facility should be working. There is no in-between with the sterilisation process – safe and complete sterilisation has either taken place or it has not.

Previous studies done by Medical Aid International where their EcoClave™ was in use showed a dramatic drop in infections, as the facilities concerned had not been sterilising properly previously.

For a busy surgical facility, it is the view of Medical Aid International that the minimum size of the main autoclaves should be 40L. Anything smaller is satisfactory for surgery that requires small instruments, such as ophthalmology, clefts and dentistry. If orthopaedic work is being done, front loading machines are recommended as the sets can be larger and need laying flat.

More on sterilisation can be seen on our website sterilisation page, where there is a video on the subject taken from our online based biomedical engineering training course.

Figure 8. While our CEO, Tim Beacon, was running a Primary Trauma Care course in rural Africa he gave a questionnaire to all the attendees on sterilisation at their healthcare facilities. None had a fully functioning autoclave.

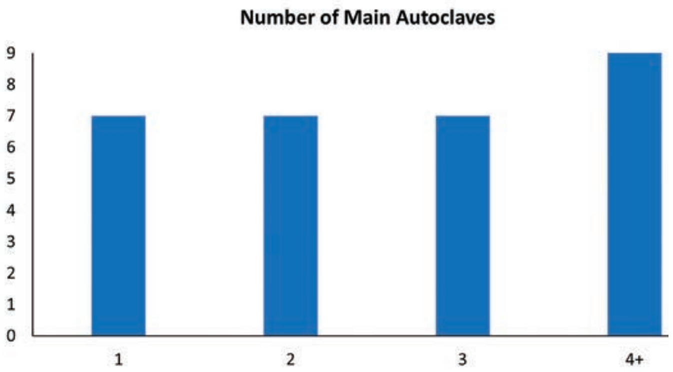


Figure 9. Count of the number of autoclaves at each healthcare facility.

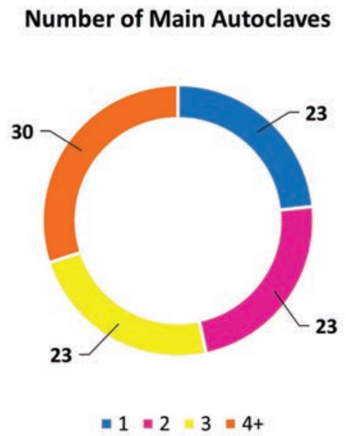


Figure 10. Proportion of facilities grouped by number of main autoclaves at each facility (in %).

- There is a broad range of autoclaves operated by healthcare facilities in LMICs, with almost each response receiving an equal proportion.
- A majority (53%) have access to 3 or more autoclaves, whilst 46% have only 1 or 2.
- There seems to be a clear divide with some facilities having access to a large number of autoclaves (4+) and some with only access to a single autoclave (23%).

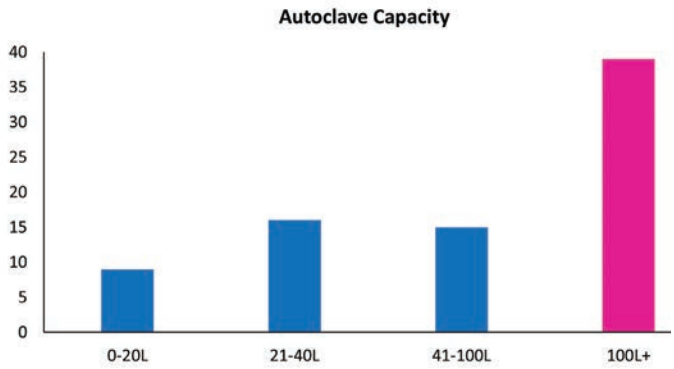


Figure 11. Count of autoclave capacity, grouped by volume. Every (up to 4) autoclave was counted at each facility, i.e. a facility with 3 autoclaves over 100L would increase the count of 100L+ by 3.

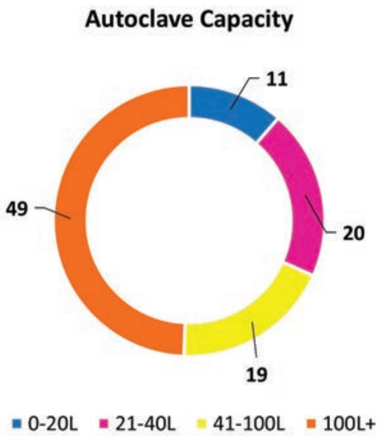


Figure 12. Proportion of autoclave capacity, counting every (up to 4) autoclave at each healthcare facility surveyed (in %).

- Whilst there is a broad mix of the number of autoclaves at healthcare facilities, the pattern when it comes to the size of autoclaves is more clear cut.
- There is high reliance on large autoclaves (100L+) for healthcare facilities' main sterilisation needs (making up 49% of the total number of autoclaves).
- Very small autoclaves (0-20L) are partially used, albeit fairly rarely (11%).

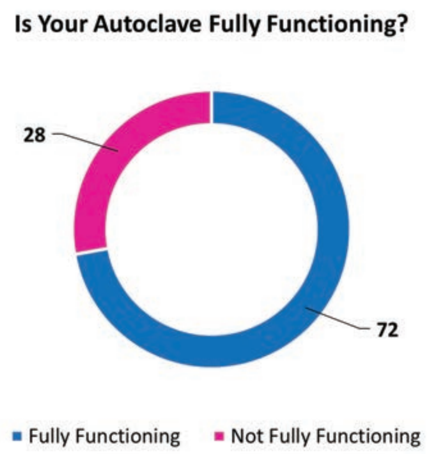


Figure 13. Proportion of autoclaves that are fully functioning, taking account of all autoclaves present (up to 4) at each facility (in %).

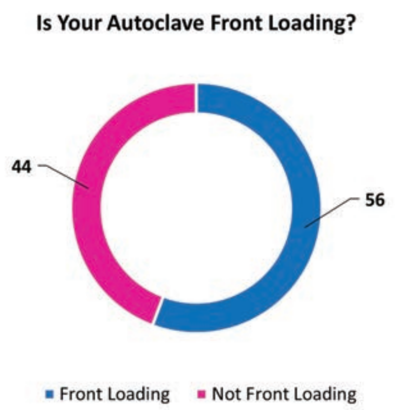


Figure 14. Proportion of autoclaves that are front loading, accounting for every autoclave (up to 4) present at each facility (in %).

- 28% of autoclaves at healthcare facilities in LMICs are not fully functioning.
- 44% of autoclaves at healthcare facilities in LMICs are not front loading.

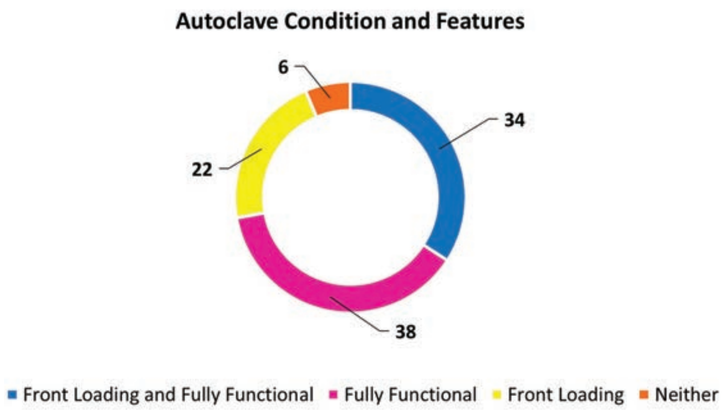


Figure 15. Proportion of autoclaves by status/ functionality in LMICs, accounting for every autoclave (up to 4) present at each facility (in %).

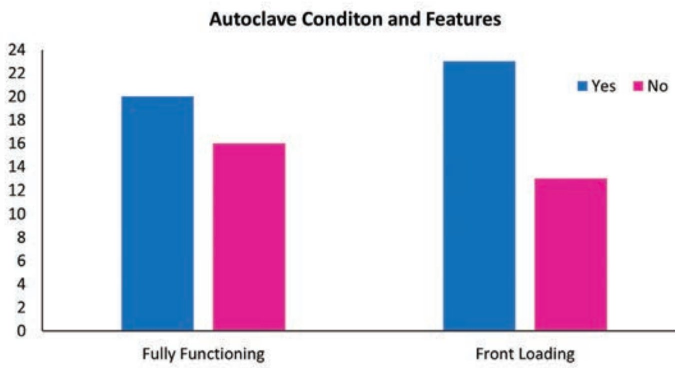


Figure 16. Count of autoclaves at healthcare facilities surveyed in LMICs.

- 34% of autoclaves were fully functional and front loading.
- 38% of autoclaves were fully functional but not front loading.
- 22% of autoclaves were front loading but not fully functional.
- 6% of autoclaves were neither front loading nor fully functional.
- Whilst 56% of autoclaves were front loading, 72% were fully functional.

It is useful to set out benchmark standards that a healthcare facility, or operating room, must achieve to be considered safe.

For sterilisation, the benchmark standards are as follows:

- All healthcare facilities must have 1 fully functioning autoclave, this is to ensure proper sterilisation of medical instruments is carried out, to keep patients safe.
- Ideally, there should be at least a backup autoclave, as well as sufficient capacity for sterilisation of all necessary equipment. However, as these criteria will vary by healthcare facility, these conditions have not been made benchmark standards.
- Additionally, having access to a front loading autoclave is useful, but not essential, so this has not been made a benchmark standard.

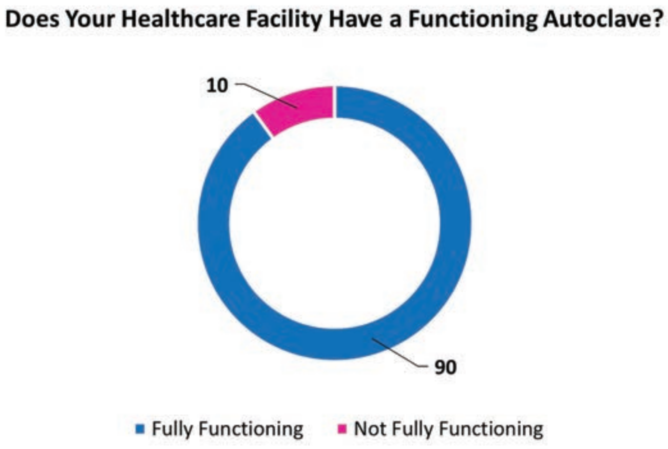


Figure 17. Proportion of healthcare facilities with/without a functioning autoclave in LMICs (in %).

- 10% of healthcare facilities do not have a fully functioning autoclave.
- This means that 90% of healthcare facilities in LMICs meet the benchmark standards for sterilisation.

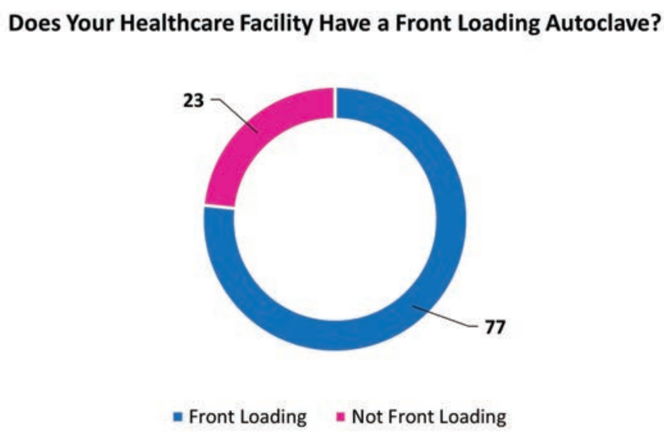


Figure 18. Proportion of healthcare facilities with one or more front loading autoclaves.

- More autoclaves are fully functioning (72%) than are front loading (56%).
- More facilities have access to a fully functioning autoclave (90%) than a front loading autoclave (77%).
- Whilst having access to a front loading autoclave is not part of the benchmark standard, just 77% would pass on this metric. This means that many healthcare facilities will not be able to implement best practice in this area.

2.3 – Anaesthetic Practices at Facilities in LMICs

General Anaesthesia – An Overview

Equipment for general anaesthesia in LMICs is generally very different to that which is used in the West. The main reason being the West has ready access to the relevant consumables, monitoring, and expensive servicing regimes that are required for the modern day, complex machines that are used.

Generally, the way an anaesthetic machine keeps a patient asleep is through the carrier gas being used by the anaesthetic machine travelling over a vaporiser. They have an anaesthetic agent in them that vaporises and goes into the gas. This is then delivered into the patient, where it is absorbed via the lungs. This vaporiser agent keeps the patient asleep. There are three main agents we are concerned with, that keep the patient asleep: Halothane (by far the oldest available, 60 plus years), Isoflurane and Sevoflurane. Halothane is low cost; Isoflurane is more expensive, and Sevoflurane is very expensive.

An anaesthetic machine should have a ventilator on it. This is because some operations (such as abdominal or chest surgery) require the muscles to be relaxed, using a muscle relaxant drug. These drugs also stop the patient breathing, so a breathing tube (called an endotracheal or ET tube) is inserted into the windpipe, and the ventilator will breathe for the patient during the operation.

In principle there are two types of anaesthesia machines: closed and open circuit machines. These are described in more detail below.

Closed Circuit Machines

These machines recycle the carrier gas that is being breathed by the patient. The resultant carbon dioxide that the patient is producing is absorbed by a canister of soda lime in the machine.

The soda lime should be changed around every 14 hours of use (although there are many variables that impact this); it changes colour when it is losing its efficacy. Recycling the gas that is being given to the patient means that, in theory, very low flow rates of gas can be given (1-2L, or less, per minute as opposed to around 9L a minute in an open machine).

This is the major benefit of the closed circuit type of machine, as it reduces the cost of both the gas and inhalational anaesthetic agent. It does however significantly increase the complexity of the machine and the amount of monitoring required. Monitoring the patient is discussed in more detail in section 2.4, but the main monitoring required, as standard, is carbon dioxide and anaesthetic agent levels.

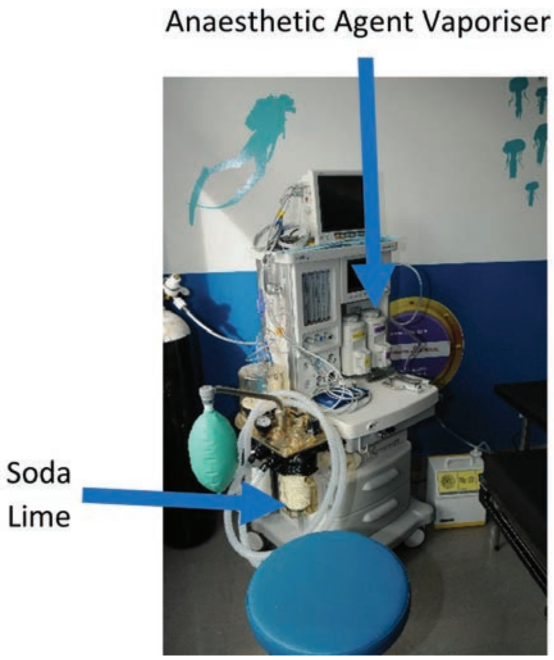


Figure 19. A circle anaesthetic machine with the soda lime shown

Monitoring carbon dioxide levels checks that ventilation is adequate (or not too excessive for mechanically ventilated patients). It can also indicate if the patient becomes disconnected from the anaesthetic circuit, if an endotracheal tube is misplaced in the oesophagus, and can be an early indicator of a sudden loss of patient circulation. Poorly functioning or spent soda lime may lead to an excessive build-up of carbon dioxide in the anaesthetic circuit.

Monitoring the anaesthetic agent ensures both that not too little anaesthetic is given, with the risk of patient awareness under anaesthesia, and that not too much anaesthetic is given.

It is the view of Medical Aid International that closed circuit circle anaesthetic machines are not appropriate for the LMIC environment, with the exception of major centres that can support the consumables and service elements and have the correct monitoring.
If these are to be installed into an LMIC, the following needs to be in place:

1. A comprehensive understanding of how to use the machine.
2. Adequate monitoring, i.e. normal parameters plus CO_2 and anaesthetic agent.
3. A reliable stock of soda lime, for frequent replacement.
4. A reliable supply of high pressure gas. This includes the small emergency cylinders to put on the machine as back up, in the event of a main supply failure.
5. A stock of consumable breathing circuits, as often reusable ones are not available.
6. Provision made for yearly servicing. This includes both availability of engineers and budgeting for the service, as there are parts that need replacing periodically, such as seals.

In addition to the above parameters, if the closed circuit machine comes from a hospital, it is very important to ensure that spares will be available in the long term, and that it is not password locked for basic maintenance work.

The reality is that unnecessary anaesthetic deaths do happen in LMICs. Sadly, during the course of writing this report, feedback from an LMIC location described how a fit child died during a straightforward procedure.

A Dangerous Anaesthetic Machine – A Case Study

On an assessment visit in an LMIC location, our CEO, Tim Beacon, visited an operating room. As usual, the standard of equipment was extremely poor. Particularly of note was the anaesthesia provision; the anaesthetic machine was very old and had numerous local adaptations made to it. The most extraordinary aspect though was the fact that it had an Enflurane vaporiser. This anaesthetic agent is now no longer available, so the anaesthetist was forced to put a totally different anaesthetic agent, Halothane, into it.

Figure 20. Modified, unsafe anaesthetic machine with no patient monitoring.

She bypassed all the safety systems in order to do this.
All vaporisers are calibrated such that the correct dosage (percentage) of anaesthetic agent is given. However, correct calibration of the vaporiser is based on the rate at which a specific anaesthetic agent vaporises. Changing the anaesthetic agent used (in this case from Enflurane to Halothane) renders the calibration useless. A 4% concentration on an Enflurane dial gives a totally different concentration of Halothane (5.5%). Discrepancies such as these can be extremely dangerous.

Additionally, there was no monitoring whatsoever on the machine, not even pulse oximetry (although our CEO had brought some pulse oximeters with him, which he gave to the team).

The operating room had a high level of usage, including treating children. We have since replaced this machine and installed proper monitoring.

Open Circuit Machines

The main difference here is that open circuit machines do not use soda lime, as described above. The gases used may come in from a combination of oxygen and room air, via cylinders, or external systems that plug into the machine via a pipeline.

The advantages of these machines are that they are much simpler, and it is possible to make an LMIC specific model which does not require the vast range of consumables or servicing that closed circuit machines do; they are therefore far more reliable, and safer. Unlike closed circuit machines, oxygen concentrators are built into them, making them self-contained, and able to work with no external support (apart from electricity). That said, there are even machines that will work without electricity and just use room air.

The main disadvantage is that the gas flow rates are higher, which is only an issue if you are using an expensive inhalational agent. Open circuit machines also come with ventilators.

You do not need to monitor anaesthetic vaporising agent or carbon dioxide, though monitoring the latter is always to be recommended, see the monitoring section 2.5.

Figure 21. An open circuit anaesthetic machine designed for the LMIC environment.

More on anaesthesia can be seen on our website anaesthetic solutions page, where there are videos on the subject taken from our online based biomedical engineering training course.

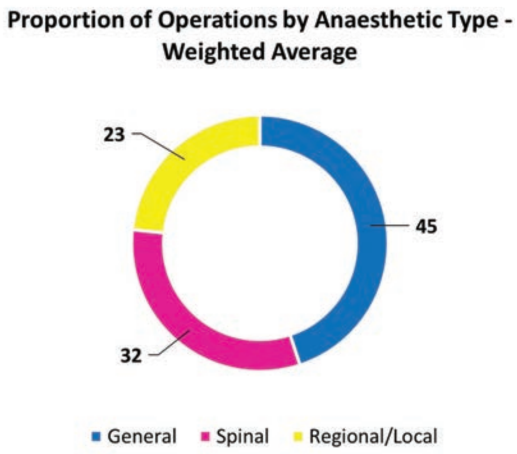


Figure 22. Weighted average of operations for all operating rooms. Calculated by weighting the declared proportion of each type of anaesthetic type used and averaging across all operating rooms. Results given in %.

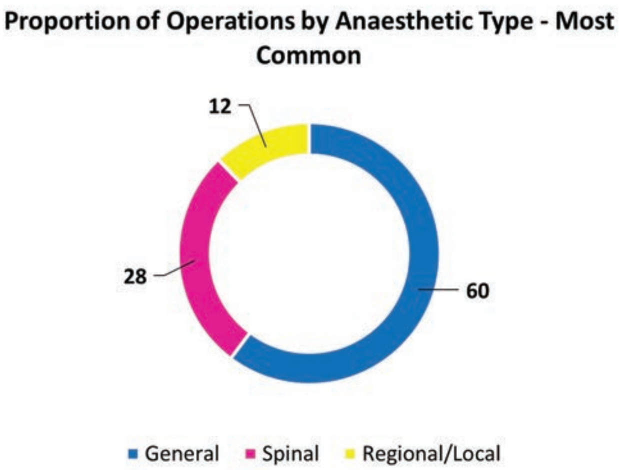


Figure 23. Weighted average of operations for all operating rooms. Calculated by counting the highest declared proportion of each type of anaesthetic type used in each operating room, and averaging across all operating rooms. Results given in %. If any results were the same, fractional values were assigned.

- Both methods produce broad agreement, although the weighted method is likely to be more accurate (as it better reflects the relative reported proportion of each type).
- The approximate proportion of operations conducted under general anaesthetic is 53%.
- The approximate proportion of operations conducted under spinal anaesthetic is 30%.
- The approximate proportion of operations conducted under local/regional anaesthetic is 18%.
- Results between operating rooms showed broad consistency, although the less frequently used operating rooms typically had more regional/local use and less spinal use.

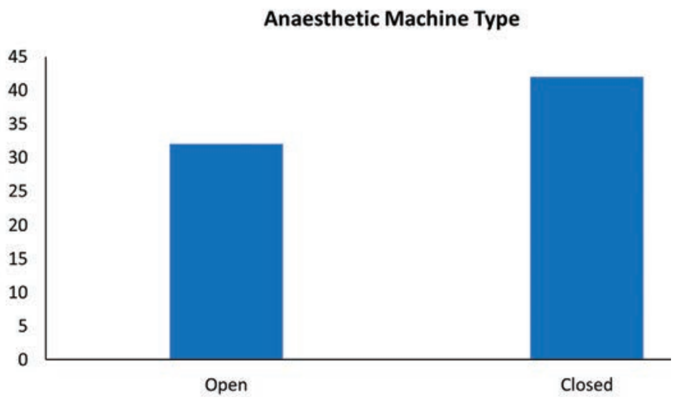


Figure 24. Count of anaesthetic machines by type across all operating rooms at all facilities. Data here is from 74 operating rooms, as 1 response reported both an open and closed machine (and was not counted).

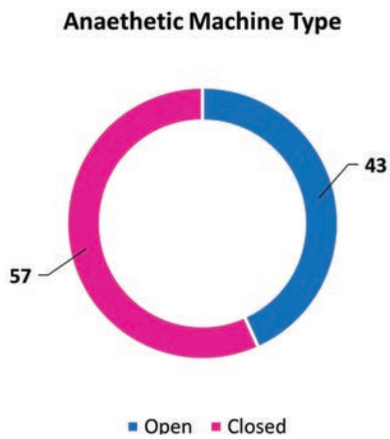


Figure 25. Proportion of anaesthetic machines by type across all operating rooms at all facilities (in %). Data here is from 74 operating rooms, as 1 response reported both an open and closed machine (and was not counted).

- The majority (57%) of healthcare facilities used closed anaesthetic machines.
- Closed anaesthetic machines are not recommended for LMICs (except in well-connected, high population areas which can support them) due to their necessary consumables to operate safely.

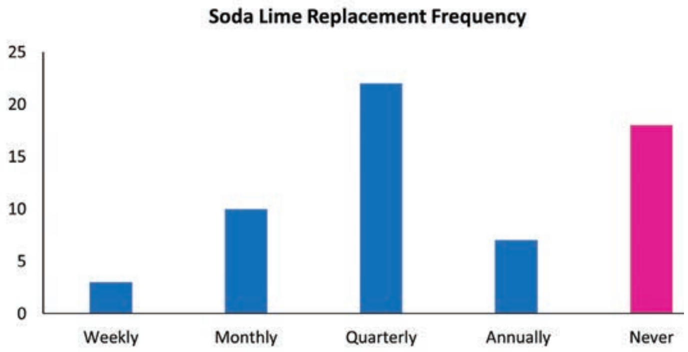


Figure 26. Count of closed anaesthetic machines by frequency at which the soda lime is replaced. Data here is from 74 operating rooms, as 1 response reported both an open and closed machine (and was not counted).

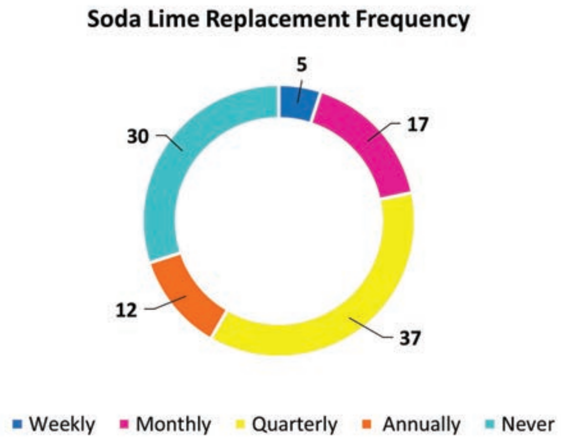


Figure 27. For each closed anaesthetic machine, proportion of each frequency at which the soda lime is replaced (in %). Data here is from 74 operating rooms, as 1 response reported both an open and closed machine (and was not counted).

- Whilst the majority of anaesthetic machines used are closed systems (57%), only 22% of these have the soda lime replaced in a safe time period (weekly or monthly).
- 70% do replace the soda lime periodically, although replacing any less often than monthly is not frequent enough.
- Concerningly, 30% who report using a closed circuit machine don't use, or never replace, the soda lime.

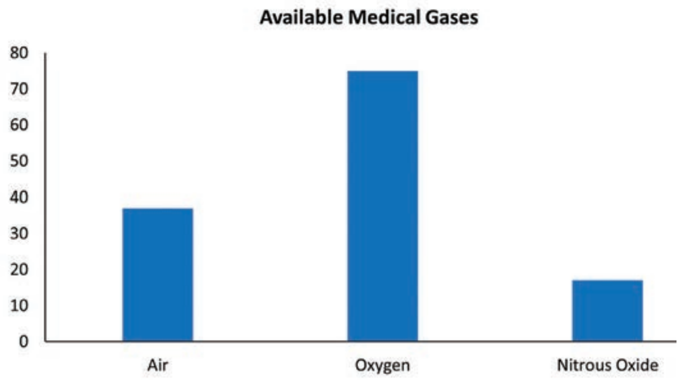


Figure 28. Count of medical gases available in each operating room surveyed.

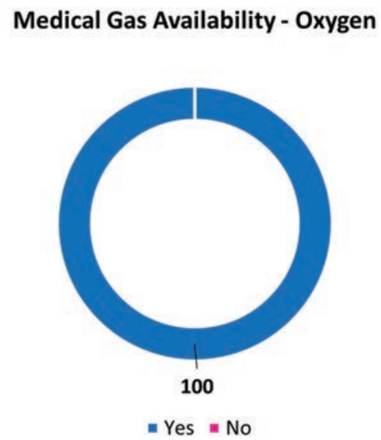


Figure 29. Proportion of operating rooms with access to oxygen as a medical gas (in %).

- Oxygen is by far and away the most commonly used, and accessible medical gas.
- All operating rooms had access to oxygen as a medical gas.

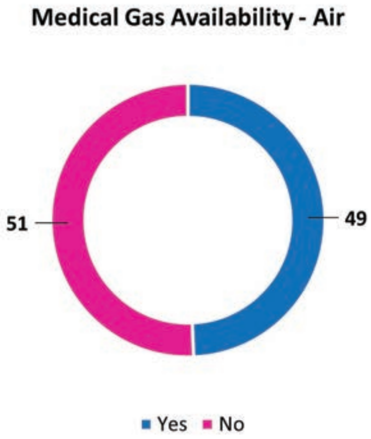


Figure 30. Proportion of operating rooms with access to air as a medical gas (in %).

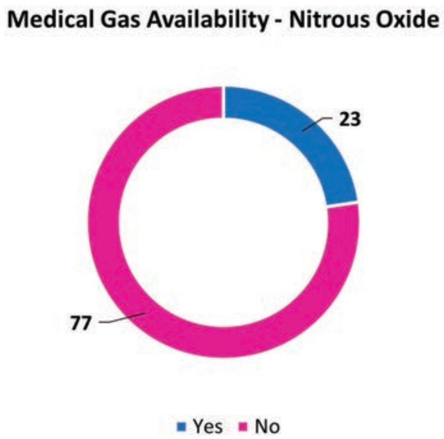


Figure 31. Proportion of operating rooms with access to nitrous oxide as a medical gas (in %).

- Whilst all operating rooms had access to oxygen as a medical gas, just under half (49%) had access to air.
- This proportion drops even further when considering nitrous oxide as a medical gas, with only 23% of operating rooms having access to it.

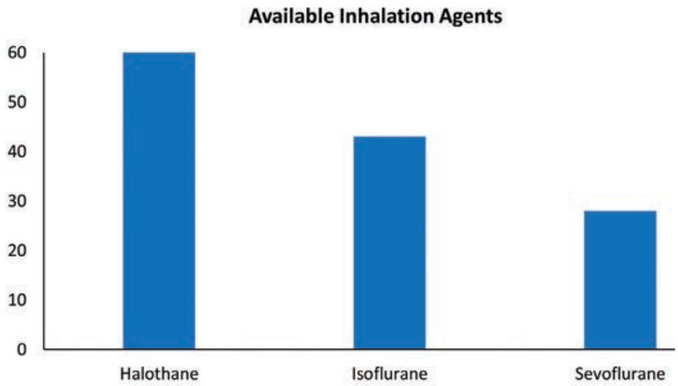


Figure 32. Count of inhalation agents available in each operating room surveyed.

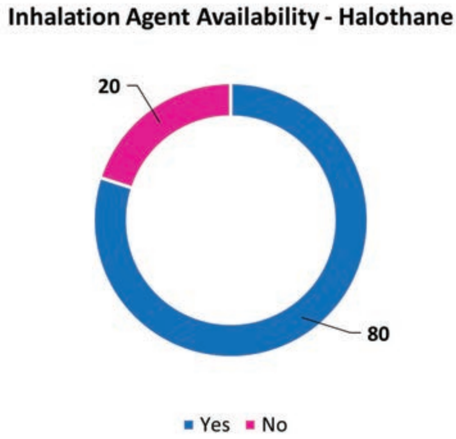


Figure 33. Proportion of operating rooms with access to Halothane (in %).

- By far and away Halothane is the inhalation agent of choice in LMICs, with almost all (80%) having access to it.
- Facilities that use Sevoflurane typically rely on another inhalation agent, with just 2 operating rooms exclusively using Sevoflurane.
- Isoflurane has moderate usage with Sevoflurane having more limited usage.

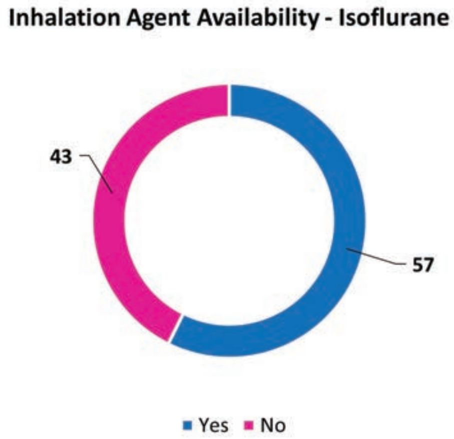


Figure 34. Proportion of operating rooms with access to Isoflurane (in %).

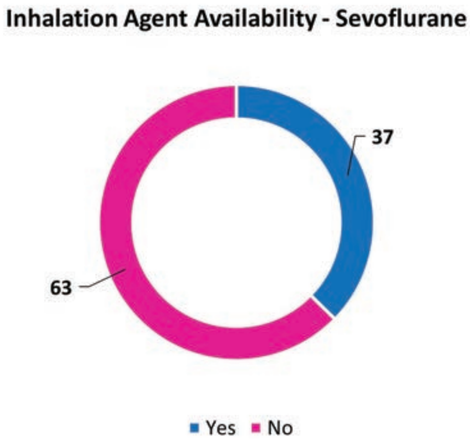


Figure 35. Proportion of operating rooms with access to Isoflurane (in %).

- Isoflurane has a slim majority of operating rooms that use it (57%).
- Sevoflurane sees some usage, although it is not particularly widespread (37%).

It is useful to set out benchmark standards that a healthcare facility, or operating room, must achieve to be considered safe. It is helpful to cumulatively apply criteria that is progressively more stringent. In so doing, it is possible to identify which anaesthetic machines meet the benchmark standards as a whole, rather than simply individual elements of the benchmark standards. These tests have been cumulatively applied to the data above, as well as data found in patient monitoring, section 2.4.

For anaesthetics, the benchmark standards are as follows:

- The anaesthetic machine must either be an open circuit machine, or a closed circuit machine with the soda lime being replaced every week or month. This ensures carbon dioxide is filtered out, preventing carbon dioxide poisoning of the patient.
- It must also either be open circuit, or a closed circuit machine with appropriate monitoring, i.e. both carbon dioxide and anaesthetic agent monitoring. This is to prevent (or alert medical staff to) either the carbon dioxide or anaesthetic agent concentration from reaching unsafe levels.
- Whilst Medical Aid International does not recommend closed circuit machines in LMICs, in general, if they have the necessary consumables replaced at the correct frequency and have the correct monitoring, they can be used safely – hence why a closed circuit machine does not mean an operating room will fail to meet the benchmark standards automatically.

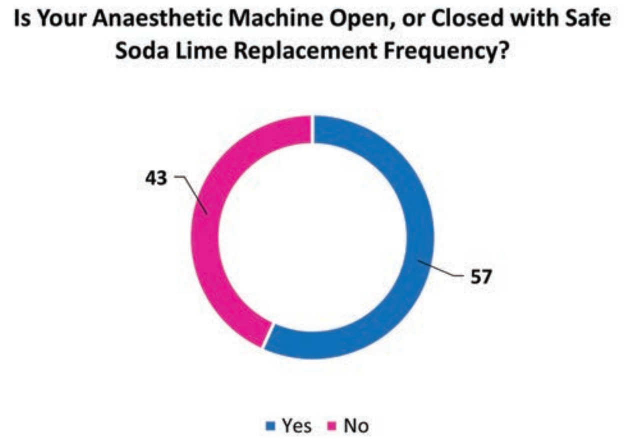


Figure 36. Proportion of operating rooms with either an open anaesthetic machine, or a closed anaesthetic machine with soda lime replaced either weekly or monthly (in %). Data here is from 74 operating rooms, as 1 response reported both an open and closed machine (and was not counted).

- Only 57% of operating room anaesthetic machines meet the benchmark standards for either being open, or closed with soda lime replacement every week or month.

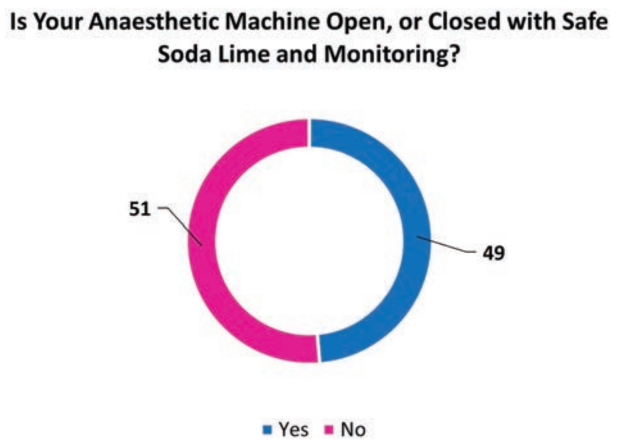


Figure 37. Proportion of operating rooms with either an open anaesthetic machine, or a closed anaesthetic machine with soda lime replaced either weekly or monthly and both carbon dioxide and anaesthetic agent monitoring (in %). Data here is from 74 operating rooms, as 1 response reported both an open and closed machine (and was not counted).

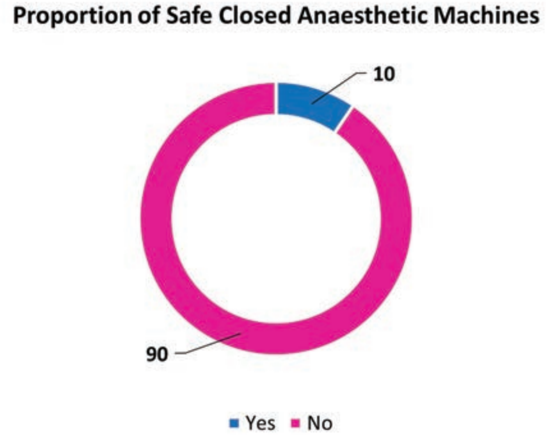


Figure 38. Proportion of operating rooms with safe closed anaesthetic machines (i.e. meet our benchmark standards), of those that use closed anaesthetic machines (in %). Data here is from 42 operating rooms. 1 response put both an open and closed machine (and was not counted).

- When considering both the benchmark standards of having soda lime replaced every week/ month, and carbon dioxide and anaesthetic agent monitoring, a minority of 49% met both standards.
- When looking at closed anaesthetic machines alone, only 4 of 42 (10%) met all our benchmark standards, and can be considered safe. This is why Medical Aid International recommends the use of open anaesthetic machines in LMICs.

2.4 – Patient Monitoring at Facilities in LMICs

Patient Monitoring – An Overview

This is an area where standards between the West and LMICs vary, and trying to obtain a cost effective solution is challenging.

In the West a patient would have the following basic parameters monitored for any operation:

- ECG (heart rhythm and rate)
- Blood pressure (BP)
- Oxygen saturation (SpO_2)
- Carbon dioxide levels/respiratory rate
- Anaesthetic agent (in closed circuit anaesthetic machines)

Additionally, there should be accessories that cover the entire age range, neonatal to adult.

To do the above reliably requires sophisticated and expensive monitoring equipment, so inevitably in LMICs compromise has been reached. How acceptable this is remains open for debate.

We believe the absolute minimal monitoring on a patient should be pulse oximetry and blood pressure, not just pulse oximetry (this is reflected in our own Surgical Checklist, see Appendix B).

That said, the ability to monitor carbon dioxide (called capnography) is also a very useful adjunct. This is because it gives an instantaneous indication when a patient stops breathing, as opposed to a pulse oximeter which will initially still indicate that oxygen levels are stable. This period of time can be anywhere from 30-60 seconds, even after a patient has stopped breathing. However, a reliable handheld combination SpO_2/capnography device is approximately seven times more expensive than a standard pulse oximeter.

There is an additional, very important benefit of carbon dioxide monitoring concerning the process of putting a breathing tube into the lungs. It can sometimes be easy to put the tube in the oesophagus and not the windpipe, which is potentially fatal. This mistake can take time to notice if the anaesthetist is inexperienced or does not follow basic protocols such as listening to air entry into the lungs. A capnograph will instantly indicate on the monitor if the tube is in the correct place, as it will register the carbon dioxide being produced by the lungs.

If Medical Aid International is equipping an operating room, we always install a monitor that tracks the following parameters:

- ECG
- BP
- SpO_2
- Capnography
- Temperature

We supply two of each accessory size from neonate to adult. It is our belief this should be the normality. The monitors are all used in the British NHS system.

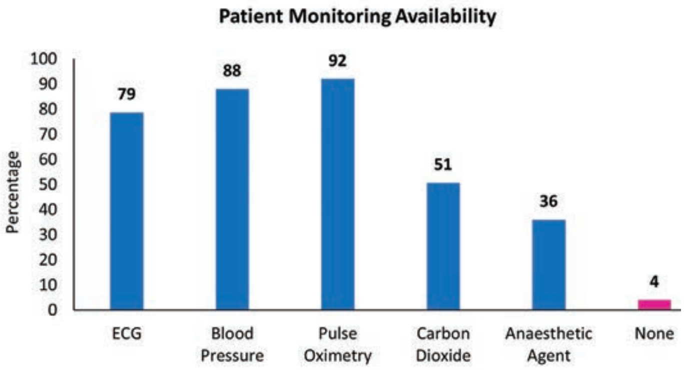


Figure 39. Proportion of patient monitoring solutions, by type, at each operating room (in %).

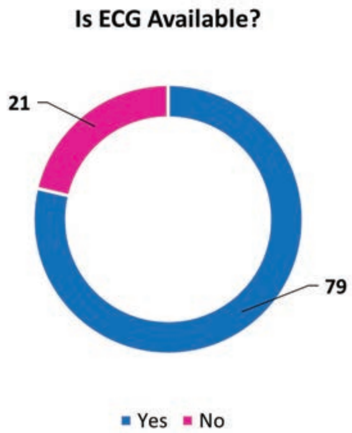


Figure 40. Proportion of operating rooms with ECG monitoring available (in %).

- Can be broadly split into 2 categories: methods with high usage, and those with lower usage.
- ECG, blood pressure and pulse oximetry are widely used.
- Carbon dioxide and anaesthetic agent monitoring are less widely used.
- 4% of operating rooms have no monitoring.

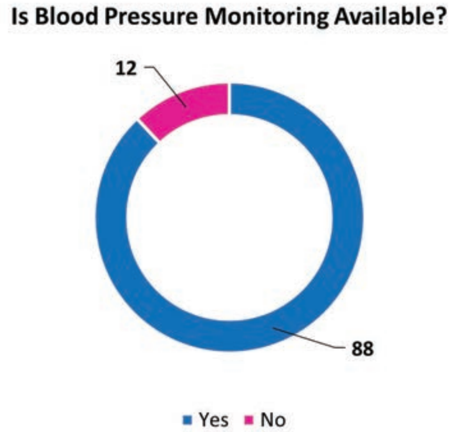


Figure 41. Proportion of operating rooms with blood pressure monitoring available (in %).

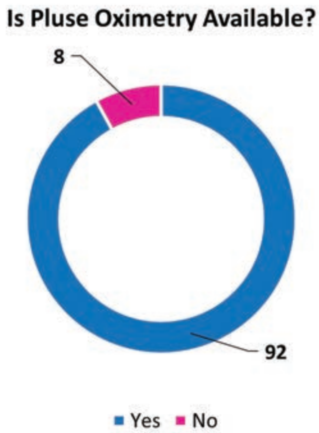


Figure 42. Proportion of operating rooms with pulse oximetry available (in %).

- Both blood pressure monitoring and pulse oximetry are widely used in LMICs.
- 88% of operating rooms had access to blood pressure monitoring.
- 92% of operating rooms had access to pulse oximetry, the highest proportion of the monitoring solutions.

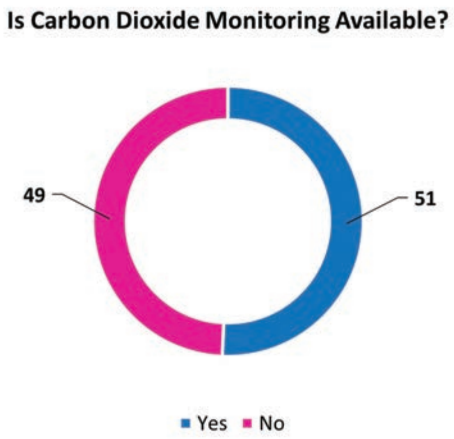


Figure 43. Proportion of operating rooms with carbon dioxide monitoring available (in %).

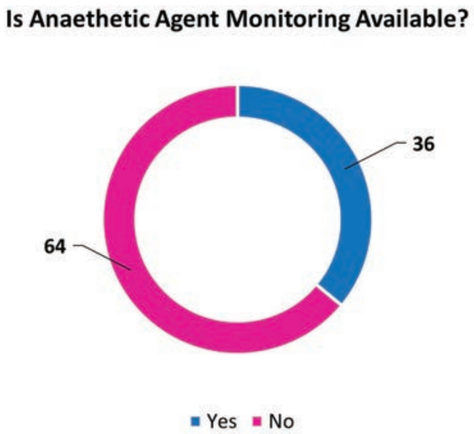


Figure 44. Proportion of operating rooms with anaesthetic agent monitoring available (in %).

- Carbon dioxide and anaesthetic agent monitoring are less widely used in LMICs.
- 51% of operating rooms have access to carbon dioxide monitoring.
- Just 36% of operating rooms have access to anaesthetic agent monitoring, the lowest proportion of any of the monitoring solutions.

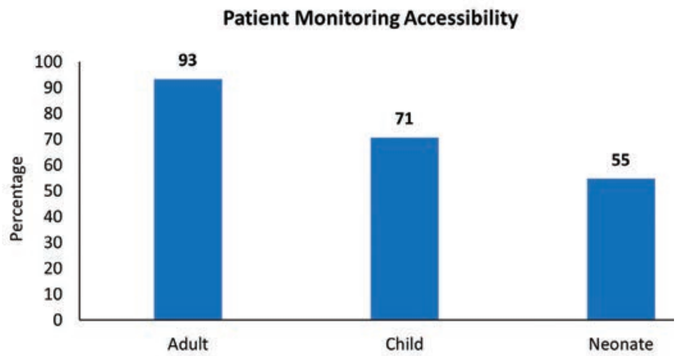


Figure 45. Proportion of patient monitoring available by accessory size (in %).

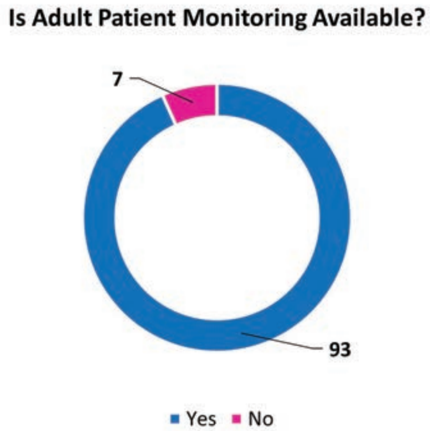


Figure 46. Proportion of patient monitoring available with adult sized accessories (in %).

- There is broad availability of patient monitoring for adults in LMICs (at 93%).
- The picture is more mixed for children and, particularly, neonates.

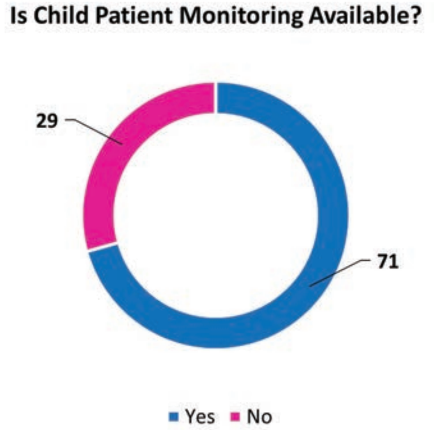


Figure 47. Proportion of patient monitoring available with child sized accessories (in %).

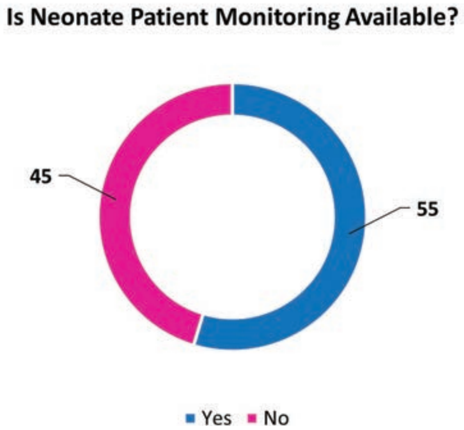


Figure 48. Proportion of patient monitoring available with neonate sized accessories (in %).

- Nearly three quarters (71%) of all operating rooms had accessories that allow for child patient monitoring.
- This figure drops to 55% when considering neonates.

It is useful to set out benchmark standards that a healthcare facility, or operating room, must achieve to be considered safe. It is helpful to cumulatively apply criteria that is progressively more stringent. In so doing, it is possible to identify which monitoring solutions meet the benchmark standards as a whole, rather than simply individual elements of the benchmark standards. These tests have been cumulatively applied to the data above.

For patient monitoring, the benchmark standards are as follows:

- Must have pulse oximetry and blood pressure monitoring available.
- Monitoring must be available in all sizes, adult, child and neonate.
- Monitoring required for safe anaesthesia (carbon dioxide and anaesthetic agent monitoring) is considered in section 2.3.
- We consider these standards to be the absolute minimum, due to cost constraints in LMICs. We recommend far more thorough patient monitoring that the above.
- For example, Capnography should be used wherever possible during general anaesthesia.

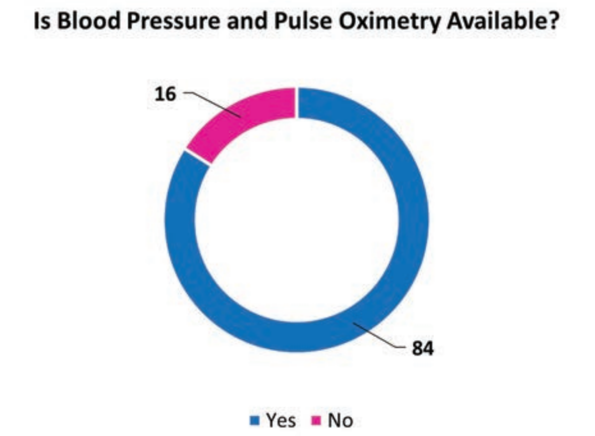


Figure 49. Proportion of operating rooms with both blood pressure monitoring and pulse oximetry available (in %).

- A significant majority (84%) have both blood pressure and pulse oximetry available.
- However, this is considered to be the absolute bare minimum benchmark standard, and is not to be recommended.

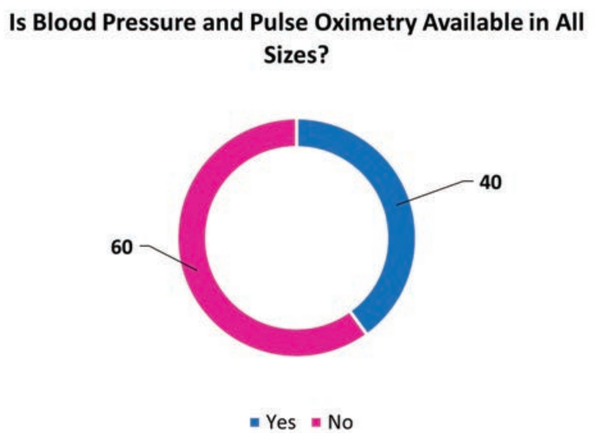


Figure 50. Proportion of operating rooms with both blood pressure monitoring and pulse oximetry available in all sizes (adult, child, and neonate) (in %).

- When factoring in the availability of correctly sized accessories, the figures for patient monitoring look far less impressive.
- Only 40% of operating rooms meet the benchmark standards, having both blood pressure and pulse oximetry available in all sizes (adult, child, and neonate).

2.5 – Operating Table Conditions at Facilities in LMICs

Operating Tables – An Overview

A fully functioning operating table for LMICs needs the following attributes:

- It needs to be manually operated. Electric tables are far more complex, the backup batteries wear out, and there are cross continent voltage issues. This means there is a danger of electronics being ruined if, for instance, an operating table from America goes to Africa, and a step-down transformer is not used.
- They need to be able to tilt head down in case the patient is sick (this is also very useful for obstetric fistula surgery). They must also be able to move up and down, to cater for different heights of the surgeon, and also different surgical procedures. For instance, ENT and eye surgery can be much more challenging if the operating table does not go up and down.
- They must have a complete mattress so that no metal is exposed, otherwise there is a high risk of diathermy/ESU burns.
- They need a full range of basic attachments in order to be used effectively, namely lithotomy poles for obstetric, gynae, and rectal procedures; an arm table for upper limb operations; and arm boards for IV access in some cases.

More on operating tables can be seen on our website operating tables page, where there is a video on the subject taken from our online based biomedical engineering training course.

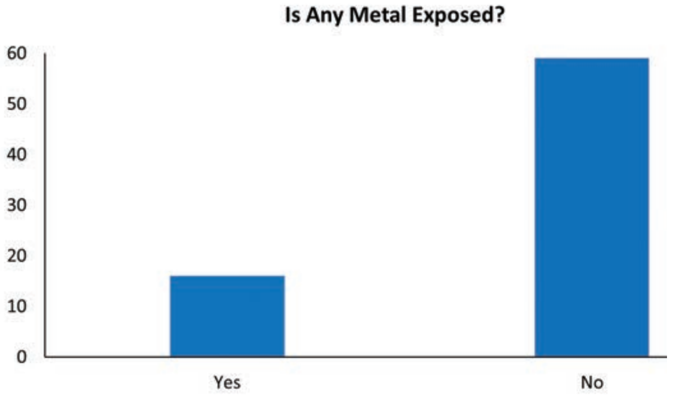


Figure 51. Count of the number of operating tables with bare metal exposed, across all operating rooms.

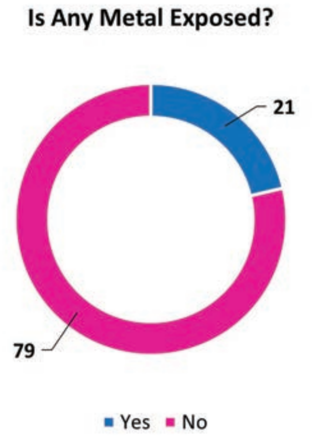


Figure 52. Proportion of operating tables with bare metal exposed across all operating rooms (in %).

- 16 operating tables had bare metal exposed, 59 did not.
- The rate of 21% of operating tables with bare metal exposed is concerning.
- This puts patients at high risk of diathermy/ESU burns.

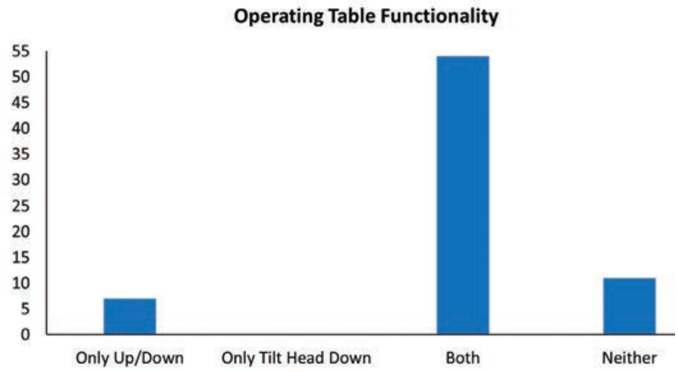


Figure 53. Count of operating tables in each operating room by functionality.

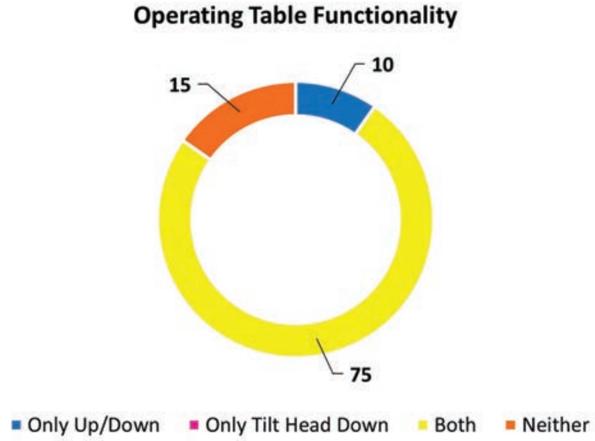


Figure 54. Proportion of Operating tables in each operating room by functionality (in %).

- 15% (11) operating tables cannot move up and down or tilt head down (Trendelenburg position).
- 10% can only move up and down.
- This leaves 75% of operating tables with good functionality (i.e. having both features).

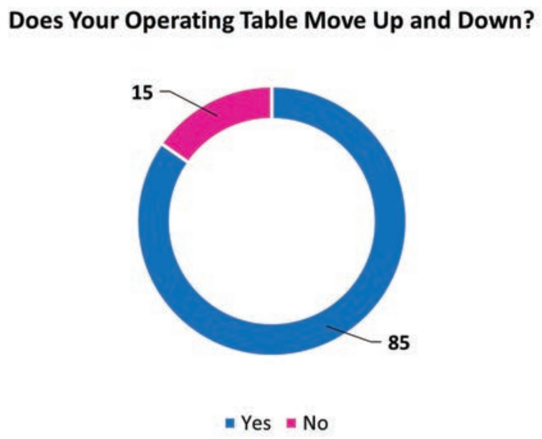


Figure 55. Proportion of Operating tables in each operating room which are able to move up and down (in %).

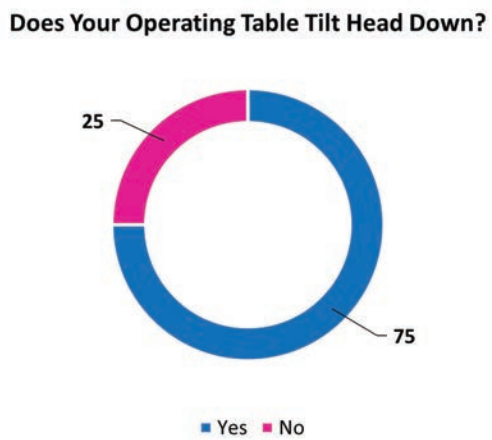


Figure 56. Proportion of Operating tables in each operating room which are able to tilt head down (in %).

- Broken down into simple percentages, 85% of operating tables can move up and down.
- The statistics are worse for tilting head down (Trendelenburg position), with 75% having this feature.

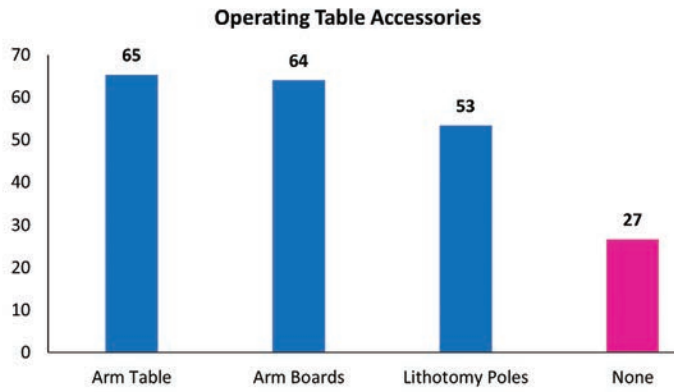


Figure 57. Proportion of operating tables, across all operating rooms, with access to a variety of accessories (in %).

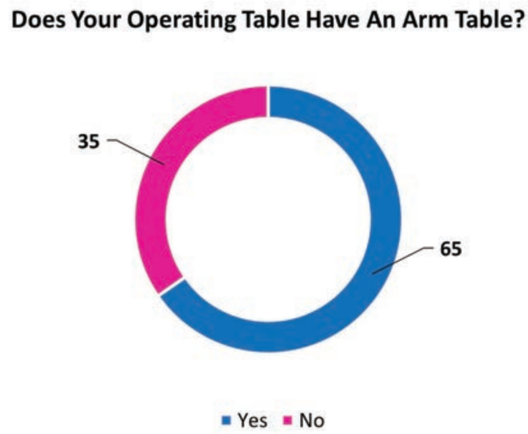


Figure 58. Proportion of operating tables, across all operating rooms, with access to an arm table (in %).

- The rate of accessories ranges from 65-53% across all the items.
- Of a total of 75 operating tables, the number of operating tables with each accessory were as follows: arm table (49), arm boards (48), lithotomy poles (40), none (20).

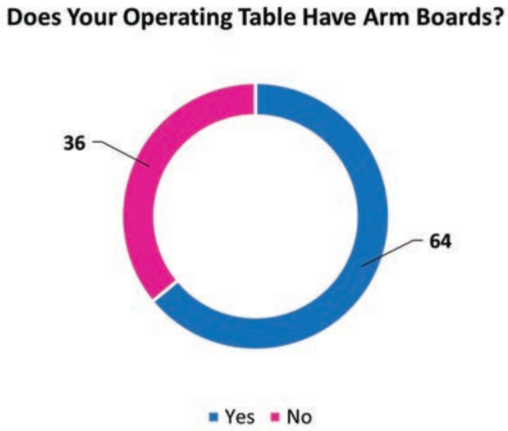


Figure 59. Proportion of operating tables, across all operating rooms, with access to arm boards (in %).

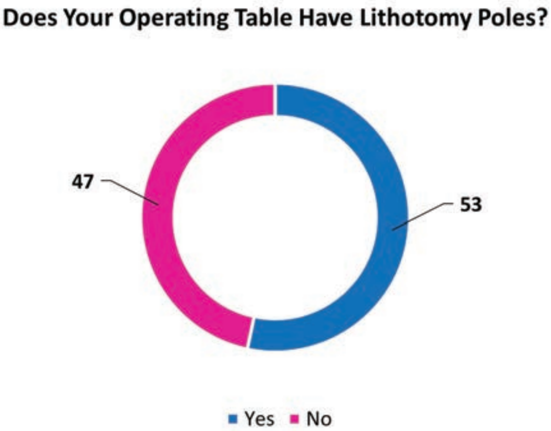


Figure 60. Proportion of operating tables, across all operating rooms, with access to lithotomy poles (in %).

- Arm tables are the most frequently found accessory (at 65%), followed by arm boards (at 64%), with lithotomy poles being the least present (at 53%).

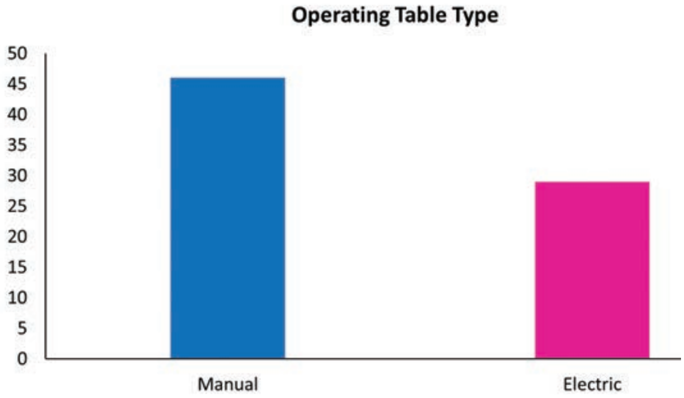


Figure 61. Count of the number of operating tables, across all operating rooms, by type.

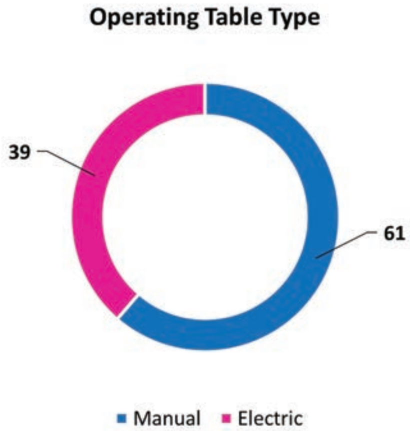


Figure 62. Proportion of operating tables, across all operating rooms, by type (in %).

- A slight majority (61%) of operating tables were manually operated. This is encouraging as these are less likely to fail than their electric counterparts.
- Out of 75 operating tables, 46 were manually operated and 29 electrically operated.

It is useful to set out benchmark standards that a healthcare facility, or operating room, must achieve to be considered safe. It is helpful to cumulatively apply criteria that is progressively more stringent. In so doing, it is possible to identify which operating tables meet the benchmark standards as a whole, rather than simply individual elements of the benchmark standards. These tests have been cumulatively applied to the data above.

For operating tables, the benchmark standards are as follows:

- No exposed metal, which is problematic as it presents a danger of diathermy/ESU burns during surgery.
- Must be able to tilt head down, which is important if the patient is sick.
- Must be height adjustable, which is key for assisting with surgery.
- Must have all basic accessories (arm table, arm boards and lithotomy poles), which are essential for safe surgery and vital for the table to be used to its full effect.
- Must be a manual operating table; electric operating tables are not to be recommended for LMIC environments. There is more to go wrong, back up batteries wear out, and there are cross continent voltage issues.

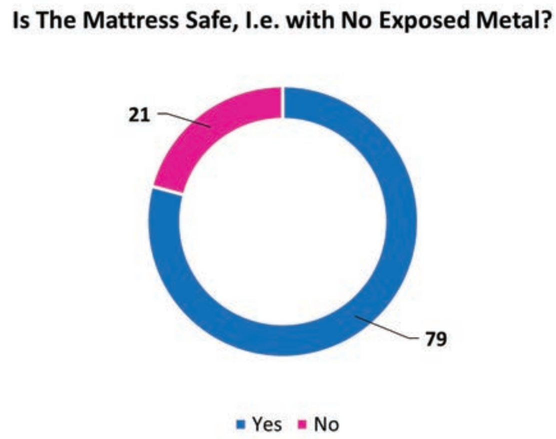


Figure 63. Proportion of operating tables which have safe mattresses, i.e. no bare metal exposed, across all operating rooms (in %).

- Applying this criteria alone (i.e. no exposed metal) results in 79% of operating tables meeting our benchmark standards.

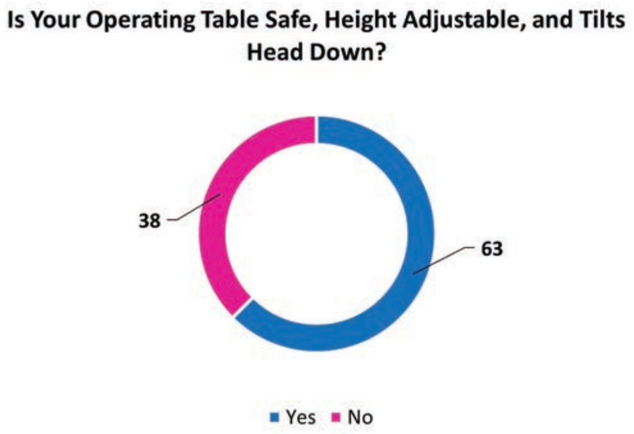


Figure 64. Proportion of operating tables which have safe mattresses, i.e. no bare metal exposed, are height adjustable, and can tilt head down, across all operating rooms (in %).

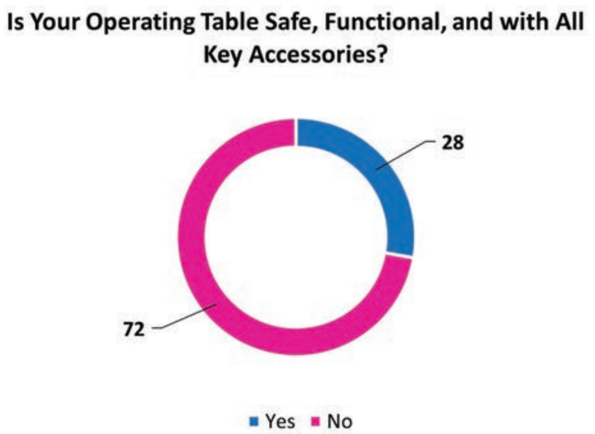


Figure 65. Proportion of operating tables which have safe mattresses, i.e. no bare metal exposed, are height adjustable, can tilt head down, and have all key accessories (arm table, arm boards and lithotomy poles), across all operating rooms (in %).

- Applying the first 2 criteria: that the operating tables must have a safe mattress and also be height and tilt adjustable, drops the proportion of operating tables that meet the benchmark standards to 63%.
- This proportion falls further to just 28% when considering if all necessary basic accessories are also present.

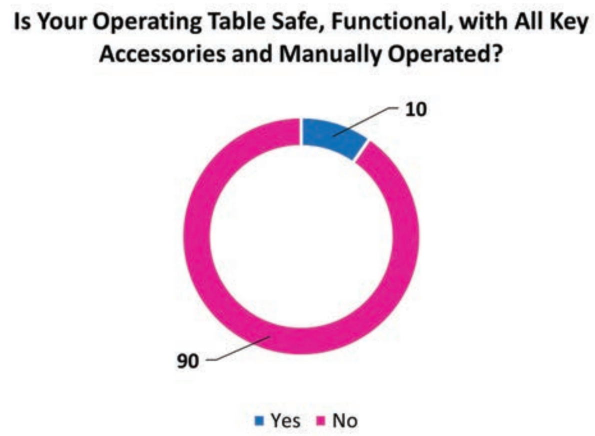


Figure 66. Proportion of operating tables which have safe mattresses, i.e. no bare metal exposed, are height adjustable, can tilt head down, have all key accessories (arm table, arm boards and lithotomy poles), and are manually operated, across all operating rooms (in %).

- Considering all the benchmark standards, only 7 of 75 operating tables can be considered safe to use. This translates to a meagre 10%.
- When considered that this situation is replicated across LMICs, the sad reality is that many thousands of operations are carried out on unsafe operating tables each year.

2.6 – Suction at Facilities in LMICs

Suction – An Overview

This is often not given the attention it needs and is absolutely essential for both the anaesthetist, in case a patient is sick (especially important as many operating tables in LMICs do not tilt head down, see ***Figure 56***), as well as the surgeon, who may need to suction body fluids etc. away from the patient.

The standards that Medical Aid International operate to in this area are to supply one battery backup suction device for the anaesthetist, and one mains twin bottled device for the surgeon, all with reusable bottles. This means that if there is a power failure, there is still one working suction in the operating room. In more remote environments we supply two suction machines with a battery back-up.

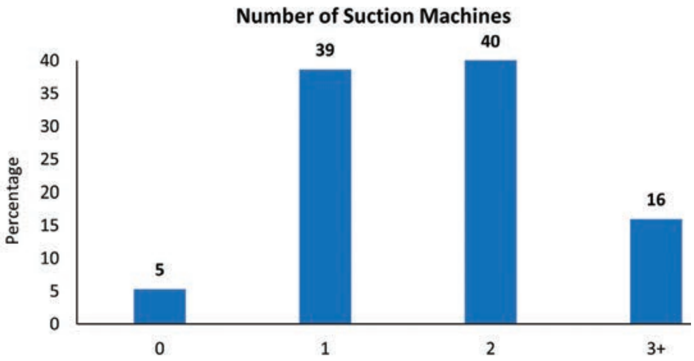


Figure 67. Proportion of the number of suction machines in each operating room (in %).

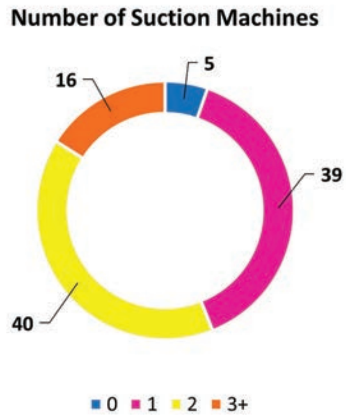


Figure 68. Proportion of the number of suction machines in each operating room (in %).

- Just over half (56%) of operating rooms are well equipped in terms of suction machines (i.e. having 2 or more).
- A further 39% have some degree of suction, even if it is not ideal.
- 5% have no suction available at all.

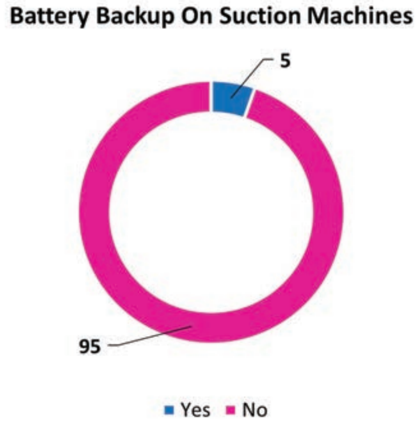


Figure 69. Proportion of suction machines with a battery backup (in %).

- Only 4 operating rooms (5%) reported having a suction machine with a battery backup.
- This is concerning as it would present difficulties during surgery if there was to be a power cut.

It is useful to set out benchmark standards that a healthcare facility, or operating room, must achieve to be considered safe. It is helpful to cumulatively apply criteria that is progressively more stringent. In so doing, it is possible to identify which suction machines meet the benchmark standards as a whole, rather than simply individual elements of the benchmark standards. These tests have been cumulatively applied to the data above.

For suction, the benchmark standards are as follows:

- Must have 2 or more suction machines in the operating room.
- Must have a battery backup on each suction machine in the operating room.

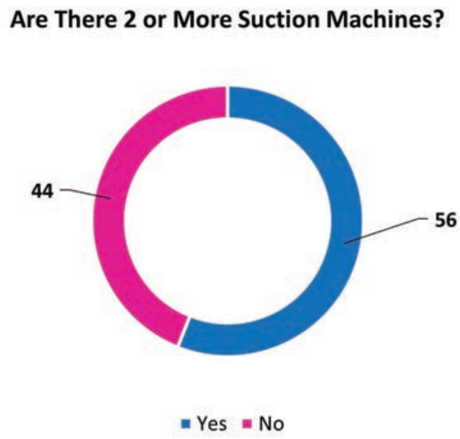


Figure 70. Proportion of operating rooms that meet the benchmark standard of having 2 or more suction machines (in %).

- It is only a slight majority of operating rooms (56%) that meet the benchmark standard of having 2 or more suction machines.

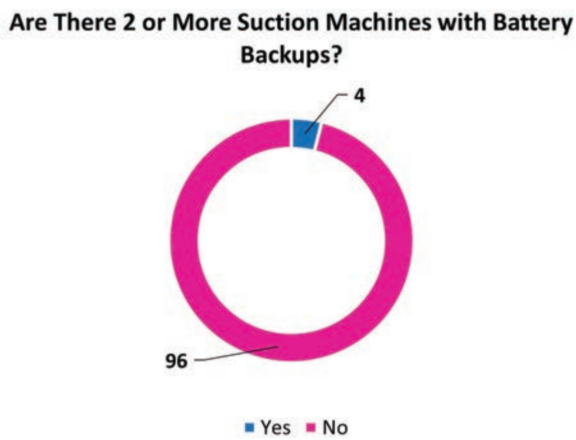


Figure 71. Proportion of operating rooms that meet all benchmark standards, i.e. having 2 or more suction machines and battery backups for each suction machine (in %).

- Only 4 suction machines across the 75 operating rooms had a battery backup.
- This is deeply concerning and is a key area of improvement for operating rooms to meet our benchmark standards.
- This means that only 4% of operating rooms meet the benchmark standards for suction.

2.7 – Oxygen Supply at Facilities in LMICs

Oxygen Supply – An Overview

LMICs have focused heavily on this particular area through Covid. In LMICs the majority of oxygen is supplied through cylinders (especially in operating rooms) and oxygen concentrators (especially on the wards).

More on oxygen supplies can be seen on our website oxygen concentrators page, where there is a video on the subject taken from our online based biomedical engineering training course.

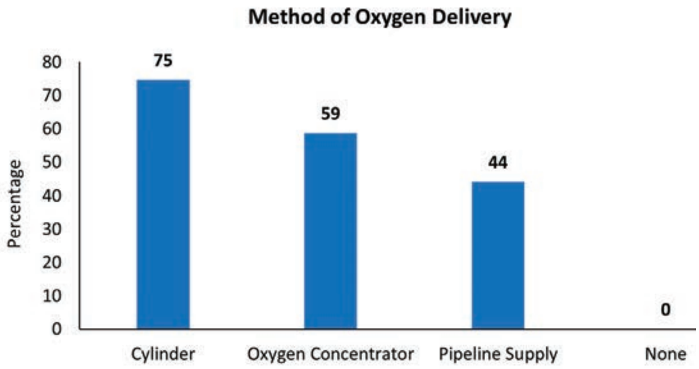


Figure 72. Proportion of oxygen delivery by method to operating rooms in LMICs (in %).

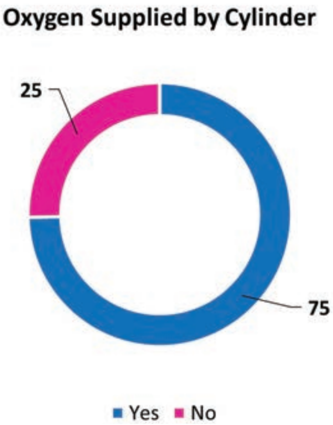


Figure 73. Proportion of oxygen delivery by oxygen cylinder to operating rooms in LMICs (in %).

- Oxygen is available in every operating room (by one or more methods) – a real positive.
- The data can be split into 2 broad categories: methods used very frequently (cylinder), and those used far less frequently (concentrator and pipeline).
- Oxygen supplied by cylinder is very common, by concentrator less so, and pipeline less so still.
- 75% of operating rooms delivered their oxygen by oxygen cylinder (although not exclusively).

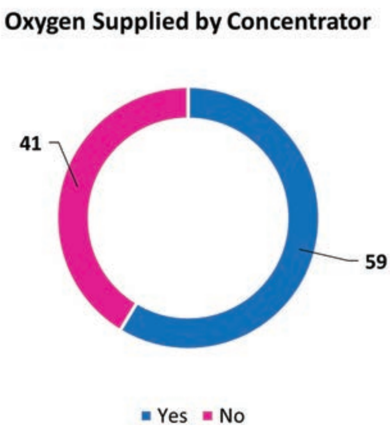


Figure 74. Proportion of oxygen delivery by oxygen concentrator to operating rooms in LMICs (in %).

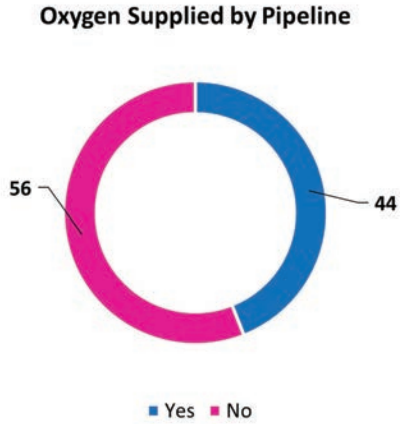


Figure 75. Proportion of operating rooms with an oxygen supply in LMICs (in %).

- Oxygen delivery using oxygen concentrators is more common than not (at 59%).
- Oxygen delivery by pipeline was far less common, being found in 44% of operating rooms.

It is useful to set out benchmark standards that a healthcare facility, or operating room, must achieve to be considered safe.

For oxygen, the benchmark standard is as follows:

- There must be an oxygen supply in the operating room.

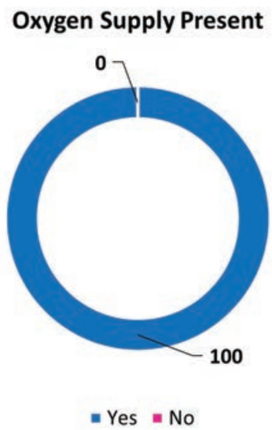


Figure 76. Proportion of operating rooms with an oxygen supply in LMICs (in %).

- As 100% of operating rooms in LMICs have an oxygen supply, all 75 operating rooms meet the benchmark standards.

2.8 – Operating Lights at Facilities in LMICs

Operating Lights – An Overview

An obviously vital part of any operating room. In LMICs the standards vary greatly, with many older lights using traditional bulbs. Background information on this area is as follows:

- Lighting technology has significantly developed over the last few years, with the advent of LED bulbs making it easier to purchase new lights as well as install them, as these new systems weigh significantly less than those supporting older bulb types.
- These new LED bulbs last many years, unlike the older style bulbs which are notorious for failing frequently.
- They can easily be supported by battery backup systems as the power required to run them is low.
- The weight of the new lights means they are less likely to drift and in general are easier to install, with roof structures having to support less weight.
- Ceiling mounted lights are not a prerequisite, mobile lights require no installation and are a perfectly acceptable solution. Indeed, they can be moved around to other rooms if required.

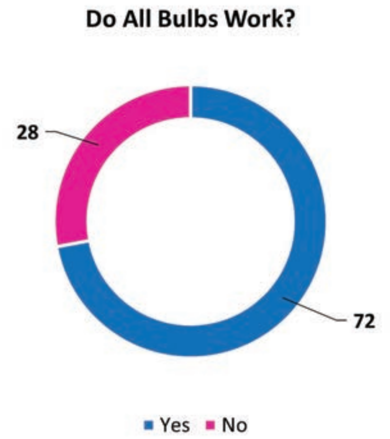


Figure 77. Proportion of operating room lights with all bulbs working, across operating rooms in LMICs (in %).

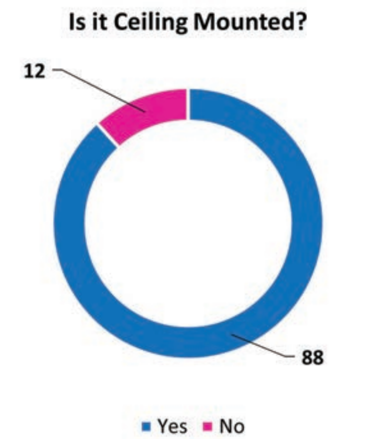


Figure 78. Proportion of operating room lights which are ceiling mounted, across operating rooms in LMICs (in %).

- Whilst the majority (72%) of operating room lights in LMICs have all their bulbs working, a significant fraction (28%) do not. This may affect the surgeon and their ability to perform safe and effective surgery.
- The overwhelming majority (88%) of operating room lights are ceiling mounted.

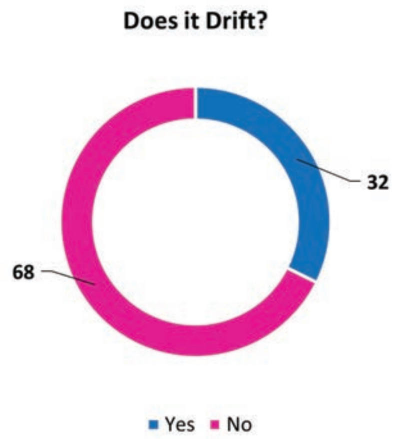


Figure 79. Proportion of operating room lights which suffer from drift, across operating rooms in LMICs (in %).

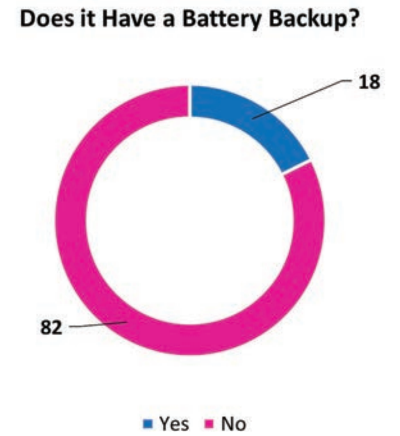


Figure 80. Proportion of operating room lights which have a battery backup, across operating rooms in LMICs (in %).

- When considering ***Figure 79***, it should be noted that a drifting operating room light is unwanted, i.e. the positive vs negative response (in terms of Yes and No) are reversed.
- Almost a third of the operating room lights (32%) suffer from drift – this is not an ideal situation, and will negatively impact surgery.
- The battery backup figures make for grim reading, with just 18% of operating room lights having a battery backup. If a power cut were to occur, this would hamper surgery.

It is useful to set out benchmark standards that a healthcare facility, or operating room, must achieve to be considered safe. It is helpful to cumulatively apply criteria that is progressively more stringent. In so doing, it is possible to identify which operating room lights meet the benchmark standards as a whole, rather than simply individual elements of the benchmark standards. These tests have been cumulatively applied to the data above.

For operating room lights, the benchmark standards are as follows:

- All bulbs must be working correctly; maximum illumination is required to allow the surgeon to optimally perform their task.
- There must be no drift. This means the light will stay where it is needed, allowing the surgeon to focus on their task rather than becoming distracted with repeatedly repositioning an operating room light.
- A battery backup must be present; this is to allow surgery to continue in a power cut.
- The operating room light may either be ceiling mounted or a mobile light, either is acceptable.

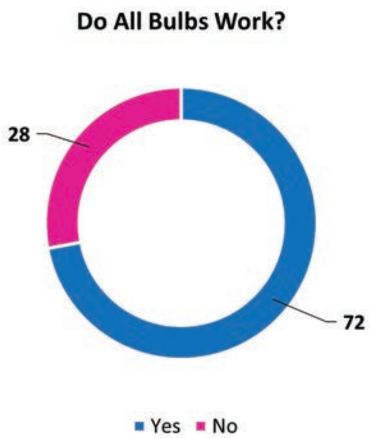


Figure 81. Proportion of operating room lights with all bulbs working, across operating rooms in LMICs (in %).

- Applying this criteria alone (i.e. all bulbs working) results in 72% of operating room lights meeting our benchmark standards.

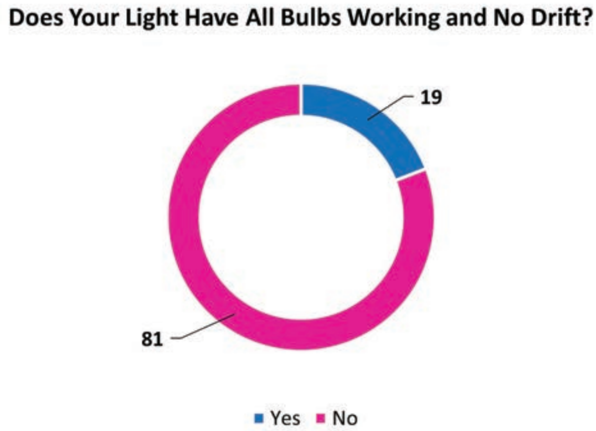


Figure 82. Proportion of operating room lights with all bulbs working, and that do not suffer from drift, across operating rooms in LMICs (in %).

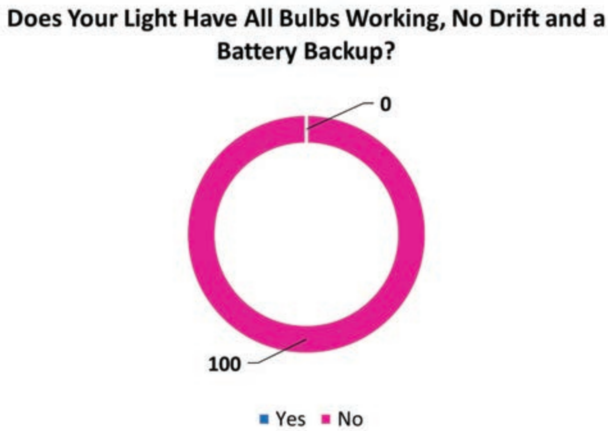


Figure 83. Proportion of operating room lights with all bulbs working, that do not suffer from drift, and have a battery backup, across operating rooms in LMICs (in %).

- Here is a very significant drop off when the “no drifting” factor is simultaneously considered. The number of operating room lights meeting both criteria fell to 19%.
- No operating room lights met all 3 benchmark standards.
- This is primarily due to only 18% meeting the battery backup standard, and 68% meeting the no drift standard.
- This is a concerning situation for healthcare in LMICs.

2.9 – Recovery Rooms at Facilities in LMICs

The Recovery Room – An Overview

This is a vital area in terms of the patient's surgical journey. It is often overlooked in the LMIC environment, hence why we devote a full section to it on our Surgical Checklist (Appendix B).

To encourage focus on this area, we plan to conduct research on this topic in a future study, as in our extensive experience the basics of care do not exist in the majority of areas. This is true both in terms of equipment, and also time allocated to the patient. For the sake of completeness, the items required, per patient, in a recovery room are:

- A trolley that tilts head down
- Oxygen
- Monitoring – SpO_2 and blood pressure
- Suction
- A means of keeping the patient warm

Additionally, there needs to be equipment to resuscitate and intubate a patient in the department.

Our all-inclusive operating room packages (Appendix A) all include one of each of the above, plus a storage trolley.

3 – CONCLUSIONS AND RECOMMENDATIONS

3.1 – Conclusions

Overall, the state of equipment in operating rooms in LMICs could use very significant improvement. A broad range of healthcare facilities across multiple LMICs were surveyed, mostly in Africa and with some representation from Asia. There was practically a 50:50 split between district and teaching hospitals. The majority of hospitals surveyed had 200+ beds, with the plurality having 2 operating rooms, therefore capturing the most likely conditions for operations in LMICs.

The number of main autoclaves varied, with facilities almost equally likely to have 1, 2, 3, or 4+ autoclaves. There was an almost even split between autoclaves that were high capacity (100L+) and smaller autoclaves (less than 100L). 72% of autoclaves were fully functioning. However, when considering healthcare facilities as a whole, 10% didn't have access to a working autoclave. In terms of front loading capabilities, 56% of main autoclaves were front loading, with 77% of healthcare facilities having access to a front loading autoclave.

The benchmark standards here were to have a functioning main autoclave at the healthcare facility. 90% met this benchmark standard. It must be stressed that this likely represents a best case scenario, see ***Figure 8***, where none of their healthcare facilities had a fully functioning autoclave.

The proportion of operations carried out under each type of anaesthetic is challenging to accurately calculate/reflect. However, using a weighted average the breakdown was: 45% general, 32% spinal, 23% regional/local. Using a "most used" tally gave slightly different, although similar, figures: 60% general, 28% spinal, 12% regional/local. The figures varied slightly depending on how frequently used the operating theatre was, with less frequently used operating rooms using less spinal and more regional/local anaesthetic. The majority used closed anaesthetic machines, although 30% did not use (or never replaced) the soda lime. 49% only changed it every year or quarter, and just 22% every month or week (a key concern). Medical gas availability had oxygen universally available, with approximately a third having access to air, and a fifth nitrous oxide. Halothane was broadly used, with wide use of Isoflurane and less frequent use of Sevoflurane.

The benchmark standards here were to either have an open anaesthetic machine, or have a closed anaesthetic machine where the soda lime is replaced weekly or monthly. Carbon dioxide and anaesthetic agent monitoring must also be present for closed anaesthetic machines. On the first benchmark standard, 57% of operating rooms met the standard, falling to 49% considering all the standards together. When considering just closed anaesthetic machines, only 4 of 42 (10%) had both an adequate soda lime replacement frequency as well as all necessary monitoring.

There was a huge range of availability of patient monitoring solutions with pulse oximetry being the most common (92%) and anaesthetic agent monitoring the least (36%). Blood pressure monitoring and ECG were broadly available, with carbon dioxide and anaesthetic monitoring used far less commonly. In terms of accessories to cater to adults, children and neonates, adult availability was high (93%) with children and neonates being significantly lower (71% and 55% respectively).

The minimum benchmark standards expected were to have both blood pressure monitoring and pulse oximetry present, available in all sizes (adult, child and neonate). Whilst 84% met the benchmark standard around patient monitoring availability, when considering if all sizes were present this fell to under half (40%).

In terms of operating tables, 21% had exposed metal, putting patients at high risk of diathermy/ESU burns. 85% of tables were height adjustable and just 75% could go into the Trendelenburg position, with 15% being able to do neither. Accessory availability was far less positive, with 27% of operating tables having no accessories. An arm table was the most commonly present (65%), followed by arm boards (64%), and lithotomy poles (53%). Manual tables made up a less than ideal 61% of the total (or 46 of 75).

When applying progressively stricter benchmark standards to operating tables, the figures are not promising. Whilst 79% passed the “no exposed metal” standard, this is narrowed to 63% when considering if the operating tables could tilt head down and were height adjustable. If the operating table must also have all key accessories, this figure is just 28%. If all benchmark standards are considered (including being manually operated), the proportion of operating tables that meet the benchmark standard is just 10% (or 7 of 65 operating tables).

Suction was only available in the necessary quantities (2+ machines) in 56% of operating rooms. A further 39% had a single suction machine, with 5% having no access to suction at all. Only 4 of 75 suction machines had battery backups (5%), a concerning statistic given the frequency of power cuts in LMICs.

Here the benchmark standards were twofold, 1 – to have 2 or more suction machines, and 2 – to have a battery backup for each suction machine. 56% were able to meet the benchmark standard of having 2 or more suction machines. That said, the fact that just 4 suction machines had a battery backup means that a measly 4% met all the suction benchmark standards.

Oxygen was available in every operating room – a real positive – with it mainly being supplied through oxygen cylinders. The use of oxygen concentrators was common (59%), and use of pipelines was not unheard of, with around half of facilities also using this method of delivery.

The benchmark standard in this area was simple – have oxygen available in the operating room via any method. All 75 operating rooms (100%) met this standard.

Lighting was a mixed affair, with 72% of operating room lights having all bulbs working and 88% being ceiling mounted. This can be sharply contrasted with the proportion of lights that were free from drift, only 32% , and the proportion with battery backups, just 18%.

If the benchmark standards are progressively applied, 72% had all bulbs working, and only 32% were also drift-free. Sadly, no operating room lights meet the benchmark standard as none also had a battery backup.

When considering our benchmark standards for each section, and looking at the proportion of healthcare facilities that passed each standard the results are, in descending order:

- Oxygen – 100% (due to Covid highlighting the need for oxygen).
- Sterilisation – 90% (due to lack of functioning autoclaves).
- Anaesthetics – 49% (mainly due to lack of soda lime replacement and poor monitoring).
- Patient Monitoring – 40% (mainly due to lack of child and neonate sized accessories).
- Operating Tables – 10% (due to a lack of necessary accessories, and electric operation).
- Suction – 4% (due to lack of battery backups).
- Lighting – 0% (due to a lack of battery backups).

Out of all 75 operating rooms, not a single one can be considered safe, i.e. meeting all our benchmark standards across all sections.

It should also be noted that this, most likely, represents a best case scenario for LMICs. Hospitals that we have worked with (and provided a place on our Biomedical Engineering Course) are probably more engaged, and better equipped than most.

If we had chosen exclusively rural locations, where we have not sent any equipment or trained any Biomedical Engineers, the results would almost certainly have been worse.

3.2 – Recommendations

Significant investment is needed across most areas to improve operating room equipment, and therefore patient care.

One area for improvement is sterilisation. With 10% of healthcare facilities not having access to a working autoclave, new and more reliable equipment should be procured to fill this critical need. Efforts on repairing existing autoclaves should also prove effective.

Another key area to improve is the lack of soda lime use in closed anaesthetic machines. With the majority using closed machines, a non-existent or infrequent replacement schedule is putting patients at risk. There are LMIC appropriate anaesthetic machines that would eliminate this problem. Likewise, it is evident that there is inadequate monitoring for closed circuit anaesthetic machines. The choice of inhalation agents could also be reflected on, with Halothane still being used widely in LMICs (although fairly widespread use of Isoflurane and Sevoflurane is encouraging).

Patient monitoring is problematic, with a significant area of concern around the size of accessories for patient monitoring, as child and neonate sizes are not sufficiently available. That said, most facilities have access to patient monitoring to some degree. However, ECG, carbon dioxide and anaesthetic agent monitoring (where required) should be areas of focus for improvement.

Operating tables also require significant investment, with many lacking the functionality and accessories needed to perform operations safely. 21% having exposed metal puts patients at very high risk of diathermy/ESU burns. 25% having insufficient functionality (missing height adjust or Trendelenburg position) again makes surgeries more complex and less safe. 27% have no accessories, again, increasing surgical risk. The fact that only 10% met our benchmark standards is deeply concerning.

A large proportion of facilities should have an additional suction machine to improve patient care. Also, supplying suction machines with battery backups should be a priority moving forward (as almost no suction machines had a battery backup).

The oxygen system in LMICs seems fairly robust, with all facilities and operating rooms having access to oxygen, either by cylinder, concentrator, or pipeline. This may be in part due to investments brought on by Covid. That said, this is not reflective of the situation in the most rural and poorly equipped hospitals, which this survey may not have reached.

Lighting is an area which could use targeted improvements. The key focus should be twofold. Firstly, improving the dismal proportion of operating room lights without battery backups (a staggering 82%). Secondly, maintaining/repairing lights so they do not drift (as 32% reported drifting). If these two factors can be improved, this should allow some operating room lights to meet the benchmark standards in future.

3.3 – Facing the Challenge: Final Thoughts from the Chief Executive Officer, Tim Beacon

I recently had a meeting with a very experienced LMIC surgeon. Part of a very well-known and respected Global Health Institution, she was a lead player in a multi-site project to improve surgical care in a challenging, remote but very heavily populated area of Africa. As part of her passion to help, she had spent a year living and working in the country we were discussing, and was a frequent visitor.

It was the sort of meeting I have on a very regular basis.

She showed me pictures of the surgical facilities in the area in which she worked; they were extremely poor, to put it mildly. Yet the solutions, as we know, are straight forward and would truly transform surgical care in the area; and yet, as ever, funds were the issue. Despite the credibility of the organisation, their presence on the ground and very wise strategic plan, adequate funds simply were not forthcoming in order to provide the correct equipment, which is, of course, essential to enable patient care to be transformed long term.

Whilst much good work does happen, the reality is there remains a major disconnect between the enormous amount of funds allocated to LMIC healthcare improvement and the provision of appropriate, sustainable operating room equipment and resources; in particular the more rural areas remain extremely poorly served. This issue has to be addressed. It is also our experience that both large and small organisations can deliver these projects, and allocation of funds to these projects should be made much simpler.

Much work in LMIC environments takes place in terms of surgical and checklist based education. This is to be highly commended, but without the necessary equipment to implement this training in full, the effectiveness of this otherwise useful training is likely to be significantly diminished. The provision of correct equipment is vital in order to support these initiatives longer term. Our experience undoubtedly shows that it is much easier to promote good practise if the healthcare team have the correct equipment.

Inappropriate Donations to LMICs

Readers of this report will undoubtedly ask the question: “how does so much inappropriate equipment end up in the LMIC environment?”. This is a deep and philosophical question. There is so much good intention and passion to help people so much less fortunate than ourselves. However, to achieve long term and sustainable benefits, this energy has to be outcome focused, taking into account the unique conditions in LMICs. Recycling equipment can be incredibly effective if it is done in a coordinated way, based on the needs of patients and the teams that support them. However, simply sending random equipment, which may not be suitable for the LMIC environment, seldom works.

Indeed, as equipment advances in the West, less and less of it has an application in LMICs. Circle anaesthesia machines abound all over the LMIC environment, yet they are often not useable due to the lack of support and consumables required for them to function correctly and safely. Many electric operating tables sit idle, broken with no chance of being repaired. It is the harsh reality that many donors may be given false hope about the benefit of equipment being donated to LMICs.

As we move forward, a team at Leeds University has developed a gasless laparoscopic surgery system[1], which is proving very effective, and directly eliminates all the challenges faced with using insufflation gas. This could be a game changer in terms of opening up the very effective world of laparoscopic surgery to low resource environments and is an excellent example of solutions being focused on the needs of the LMIC environment.

There are now a wide variety of equipment options that can create long term, effective medical solutions. It is these that need to be utilised more readily, in order to provide long term sustainability in LMIC healthcare.

It is our sincere hope that this report can act as a catalyst for change, and that the supply of suitable equipment becomes integral to the support of LMIC surgical care moving forward, so that patients who are currently so often badly served can obtain the treatment they deserve.

Tim Beacon – Chief Executive Officer, Medical Aid International

[1]Webb, M.M., Bridges, P., Aruparayil, N., Chugh, C., Beacon, T., Singh, T., Sawhney, S.S., Bains, L., Hall, R., Jayne, D., Gnanaraj, J., Mishra, A. and Culmer, P.R. (2022). The RAIS Device for Global Surgery: Using a Participatory Design Approach to Navigate the Translational Pathway to Clinical Use. *IEEE Journal of Translational Engineering in Health and Medicine,* [online] 10, pp.1–12. doi:10.1109/JTEHM.2022.3177313.

Figure 84. The morale boosting effect when a shipment arrives.

“Yesterday, we put the operating table and the anaesthesia device into operation… We also used the monitors and some oxygen concentrators immediately… Thank you very much for everything: organizing, packing, shipping and accompanying up to the arrival here.”

Figure 85. A very small UK based charity very active in a large, challenging LMIC country worked extremely hard to raise funds to improve surgical facilities there, a process in which Medical Aid International helped.

The money was raised after a lot of work, and several surgical facilities based on our operating room package have been sent to great effect.

At one site eleven caesarean sections were performed in the first four days of use; there was nowhere else for these ladies to go. What would have happened had this facility not arrived?

4 – APPENDICES

4.1 – Appendix A – Operating Room Complete Package

Medical Aid International
A Social Enterprise Supporting Healthcare in Low Resource Environments

OPERATING ROOM COMPLETE PACKAGE

Delivered crated with all accessories and operational two hours from arrival

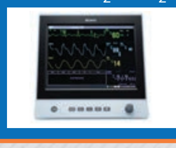
Package Includes:

Arbutus Power Tool

Diathermy/ESU

Mobile Operating Light & Head Torch

Patient Monitoring
includes ECG/ BP/SpO_2/CO_2



Tourniquet

External Fixation

Two Oxygen Concentrators

Operating Table

Theatre Furnishings
- Large & small instrument trolleys
- Drip stand
- 2 Stools
- 2 Storage trolleys
- Mayo table

Anaesthetic Machine
LMIC appropriate with ventilator

Instruments
- General
- Orthopaedic
- Obstetric
- Plastic
- Skin Graft

Autoclaves
LMIC Compatible

Two FREE Online Biomedical Engineering Courses
including toolkits & text books (Worth £4,000)

Suction

- Solution in a box – crated and easy to transport
- Includes the MAI operating table with attachments
- All equipment designed for the LMIC environment
- Suitable for all ages – neonatal up to adult
- Operational in two hours
- Contact us now to discuss options that suit your specific requirements
- Price on application

4.2 – Appendix B – MAI Surgical Preparation List

The MAI Surgical Preparation List

The list below is designed to help ensure both the operating room and the entire team are prepared for the patient's complete journey through the operating department.

BEFORE YOU START:
Does everyone know what operation is being done and their role in the team?

ANAESTHESIA

- [ ] Do you have the correct patient?
- [ ] Has the anaesthetic machine been checked?
- [ ] Do you have a working suction machine?
- [ ] Do you have adequate patient monitoring?
  Pulse oximetry and blood pressure should be the minimum
- [ ] Do you have a source of oxygen?
- [ ] Do you have working laryngoscopes?
- [ ] Do you have the relevant airway control devices such as airways, ET tubes, LMA's?
- [ ] Do you have emergency intubation aids?
- [ ] Do you have the necessary drugs and IV fluids?
- [ ] Do you have access to emergency drugs?
- [ ] Do you have access to a manual resuscitation bag?

SURGERY

- [ ] Is the operation site marked?
- [ ] Do you have the correct instruments and are they sterile?
- [ ] Is working suction available?
- [ ] Do you have the required sutures, swabs, drains, dressings, catheters?
- [ ] Does the operating light work?
- [ ] Is the operating table working and do you have the correct accessories for the procedure?
- [ ] Is a system in place to ensure full instrument, needle and swab counts are completed?
- [ ] If available is the diathermy and/or any other electrical equipment working properly?

RECOVERY

- [ ] Is someone allocated to recover the patient and stay with them until they go to the ward?
- [ ] Do they know the recovery position?
- [ ] Is oxygen available?
- [ ] Is suction available?
- [ ] Is there access to patient monitoring?
  Pulse oximetry and blood pressure should be the minimum
- [ ] Do you have access to the necessary drugs and IV fluids?
- [ ] Can you keep the patient warm?
- [ ] Is there access to emergency equipment including airway devices, manual resuscitation bags and drugs?

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