Medical Aid International

Supporting Healthcare in Low Resource Environments

MAINTENANCE LOG REPORT

August 2024

Contents

A Word from the Chief Executive

This report, another in our series exploring the challenges and solutions of LMIC biomedical engineering capacity building and support, offers a significant insight into these areas.

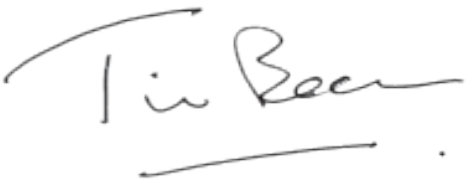
We can all learn immense amounts from looking at the data but for myself, having worked and travelled in this environment for twenty years, there are several stand out messages which we need to learn from and apply.

Firstly, the value of education and the use of the internet to facilitate this. The Medical Aid International online based course has now reached over 300 students in 23 countries, being accessed and used in the most remote locations. As our data shows, 44% of the maintenance/repair events completed in the study attributed the requisite knowledge to the course. This reflects what we hear on a daily basis and is a credit to these engineers. The impact on the ground of repairing often sub optimal equipment in order to treat patients cannot be overestimated.

Secondly, we know from this, our experience, and our equipment audits (which will be published shortly) that so much equipment that is supplied or donated, often after many years use in the West, is totally inappropriate for the environment and has not been supplied with the necessary accessories. This inevitably makes the jobs of the engineers (and clinical staff) so much harder, or impossible. Indeed, it could be argued that Table 27 proves this point; appropriate, quality LMIC appropriate equipment (which we have many years' experience of supplying) would negate the majority of these faults. The aid community should carefully consider this point.

Then of course there is the hidden value. One of our objectives when we designed our course was to make it relevant to the LMIC environment and holistic in nature, hence the first aid and train the trainer elements, both of which are shown as very helpful in our programme evaluations. We also wanted to use it as a communication tool to facilitate research and a global community of LMIC biomedical engineers. The quality of this report and others is evidence of this, something we at Medical Aid International are very proud of.

I trust you find this report helpful as we all work together to help improve the care for patients in LMICs globally.



Tim Beacon – Chief Executive Officer, Medical Aid International

Introduction

Medical Aid International, in partnership with the Intuitive Foundation, has undertaken a biomedical engineering initiative to foster biomedical engineering capacity-building in low-to-middle-income countries (LMICs). The intervention utilised the well-established Medical Aid International online based biomedical engineering programme. The foundational course comes complete with:

- Online content, with 72 videos, 15 units with 300 multiple choice questions
- A comprehensive professional toolkit, including multimeter
- Four textbooks
- Professional clothing
- City & Guilds Assured status (a globally recognised awarding body)

Additionally, to facilitate the project, each site received the following:

- Laptop, keyboard, mouse and screen
- An oxygen analyser
- Magnifying illuminated light
- Asset labels

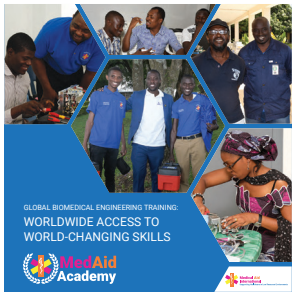
To participate in the project each hospital had to allocate a room for the biomedical engineering department to facilitate the work involved in the initiative, this comprised of six main stages:

1. Site selection
2. Onboarding survey
3. Initial audit
4. Online Biomedical Engineering Course
5. Maintenance log
6. Follow-up audit

This report evaluates 478 maintenance log entries from 18 healthcare facilities across 9 countries. The report has numerous objectives, namely investigating sources of relevant maintenance knowledge of the students (and the contribution to this from the MedAid Course), the main causes of equipment faults, and the replacement parts used during repairs.

25 facilities were enrolled in this study, at the time of writing, only 23 had completed the prerequisite initial audit. Five facilities did not contribute any entries to their maintenance log. Figure 1 illustrates the contribution of entries from each site. Many facilities struggled with the discipline of recording preventative and corrective maintenance activities, necessitating frequent reminders via email and text. Explanations for minimal contributions included:

- Limited Internet access
- Prolonged absences
- Health emergencies
- Regional conflicts preventing all non-essential work
- Perfectly functional equipment not requiring maintenance



The 32-page course booklet can be seen here.

Figure 1.

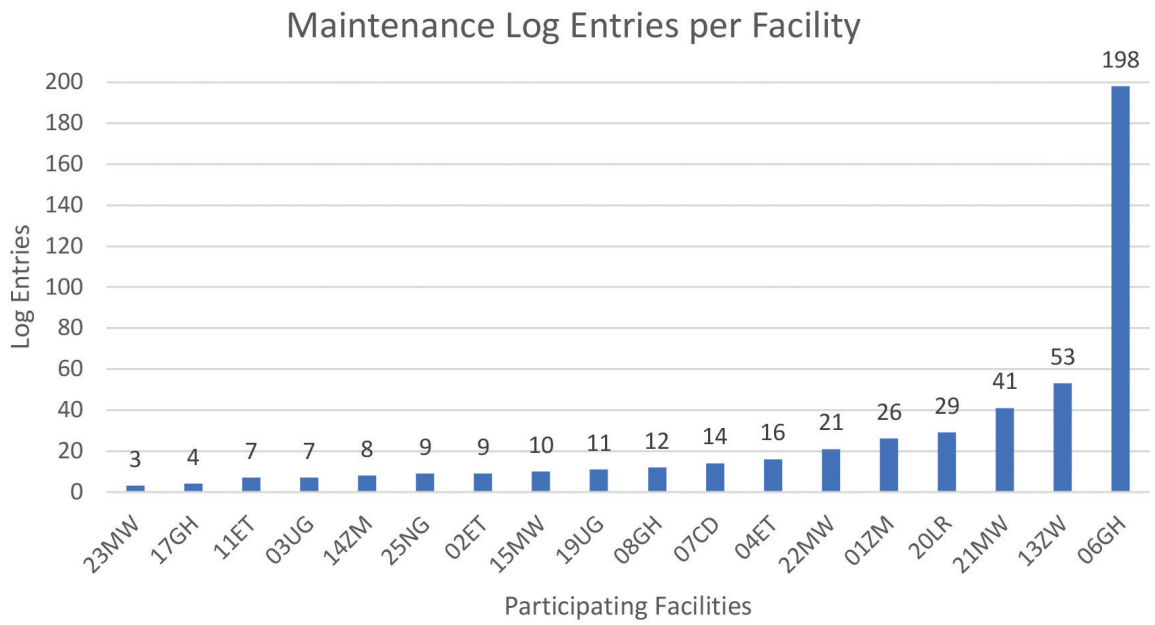
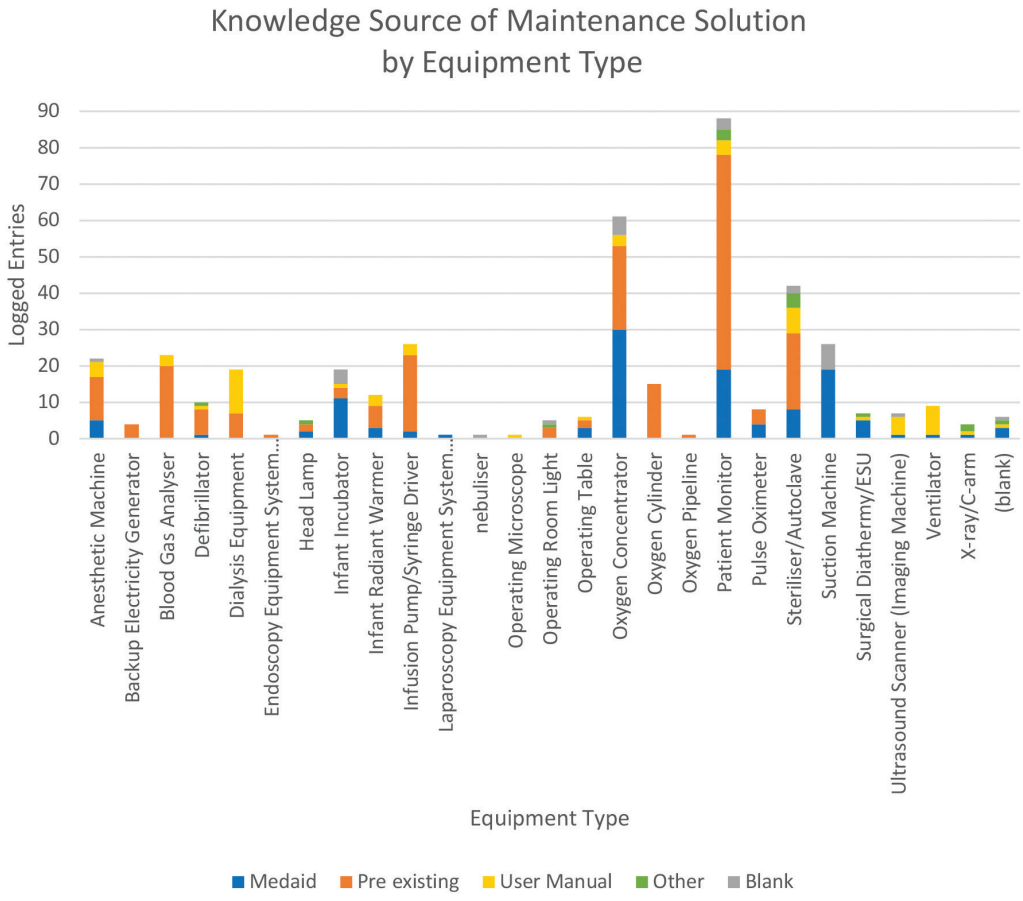


Figure 2 illustrates the distribution of equipment types recorded and the source of the implemented maintenance solution.

Figure 2.



Site 06GH was a very large site in Ghana with advanced medical equipment and a thorough maintenance regimen. Given they submitted 198 out of 478 maintenance events, 41% of the total, this site's impact on the data is oversized. The equipment for this site is also not representative of the other sites, being far more modern – almost reaching Western standards. This must be considered when reviewing the source of knowledge of the students undertaking the maintenance/repairs.

Given the oversized impact on the data of site 06GH, it is interesting to look at the data excluding this site. Figure 3a details the result of this analysis, excluding the outlier site 06GH. For clarity, blank entries have also been excluded. The MedAid course is the primary knowledge source, accounting for almost 50% of the knowledge required to complete the maintenance events.

For completeness, Figure 3b, shows the same data (with site 06GH excluded), but with the blank entries left in. The primary knowledge source is still the MedAid Course, on 40%, with the Pre-existing Knowledge accounting for 36%.

When considering all sites, most (55%) solutions for equipment faults were based off pre-existing knowledge. With the Medical Aid International (MedAid) Online Biomedical Engineering Course being the second most cited source of knowledge, at 25%. Figure 3c provides a breakdown of these sources.

Figure 3a.

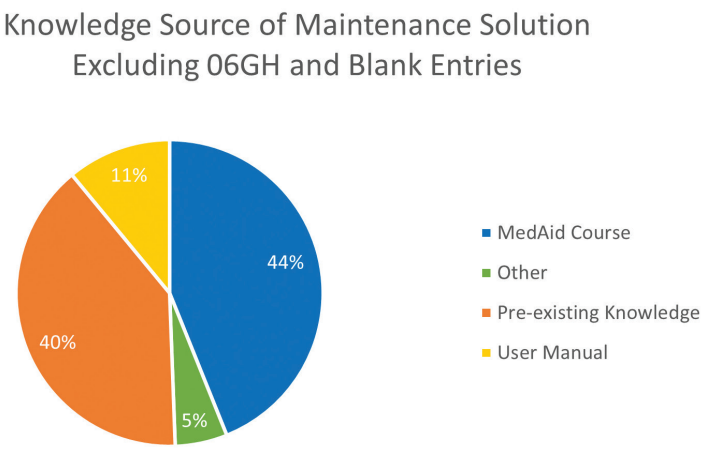


Figure 3b.

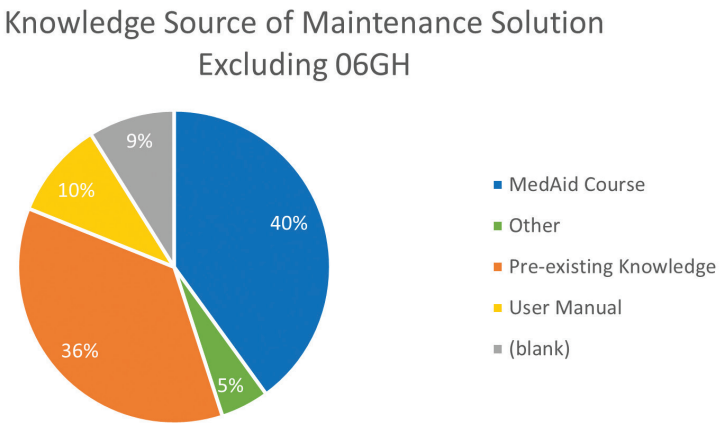
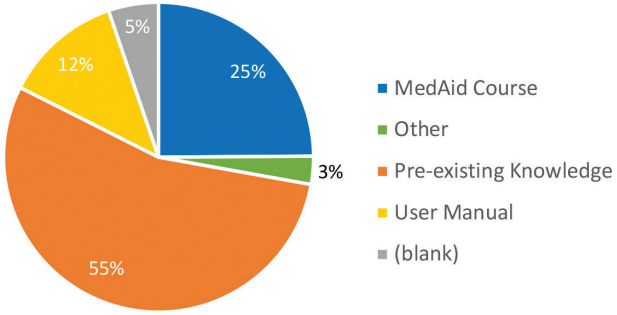


Figure 3c.

Knowledge Source of Maintenance Solution



This report serves as a summary of the maintenance log. Entries are deciphered and interpreted when exceptionally ambiguous, but all attempts were made to stay true to the original content.

Key Findings

- Top 3 most logged items of equipment:
  - Patient monitors: 88
  - Oxygen concentrators: 61
  - Suction machines: 48
- Top 3 reasons for corrective maintenance actions:
  - Faulty probes/transducers: 50
  - Damaged accessories: 38
  - Power supply issues: 35
- Top 3 items/parts used in equipment repairs:
  - Probes: 23
  - Filters: 19
  - Fuses: 19

Patient Monitors

Summary

Common issues reported for patient monitors include faulty blood pressure (BP) cuffs, SPO_2 probes, batteries, and various sensor and reading inaccuracies. Regular preventative maintenance and calibration are frequently mentioned, indicating a need for regular servicing to maintain optimal functionality. Other notable issues include faulty displays, broken components, and power-related problems. A total of 496 patient monitors were audited, with 88 entries recorded in the maintenance log.

Table 1. of Primary Issues and Reported Frequency

EQUIPMENT FAULT/ERROR	FREQUENCY
Faulty BP Cuff	18
Faulty Probes	18
Faulty SPO_2 Probe	*14*
Faulty ECG Probe[1]	*2*
Faulty Temperature Probe	*2*
PPM	15
Abnormal Readings	10
Power/Battery Faults	8
Display Problems	6
Failure To Take BP Readings	6
Speaker Malfunction	3
Faulty Pump	2
Broken Selector Knob	1
(Blank)	1
Total	**88**

[1] More commonly known as and ECG lead.

Breakdown of Issues by Category

- **Probes:** The most frequent issues are with the BP cuffs and SPO_2 probes, indicating that these components are critical points of failure.
- **Maintenance and Calibration:** Preventative maintenance and calibration are repeatedly highlighted, suggesting that routine checks are essential for these monitors.
- **Power and Charging:** Problems with batteries and power supply underscore the importance of reliable power sources.
- **Feature Malfunctions:** Display issues like faulty LCDs and black screens render the monitors effectively useless. Broken parts such as knobs and ports, along with speaker malfunctions, are also common, suggesting wear and tear or mechanical failure over time.

This analysis can help prioritise maintenance and procurement efforts to ensure the reliability and accuracy of patient monitoring.

Table 2. Spare Parts Used in Maintenance Work

PART	FREQUENCY
None	22
BP Cuff	18
Probes	18
SPO_2 Probe	*14*
ECG Probe	*2*
Temperature Probes	*2*
Simulator	9
Blank	6
Battery	5
Speaker Parts	3
Display/LCD	2
Pump	2
Air Hoses	1
Air Filter	1
Printed Circuit Board (PCB)	1
Power Cord	1
Fuse	1

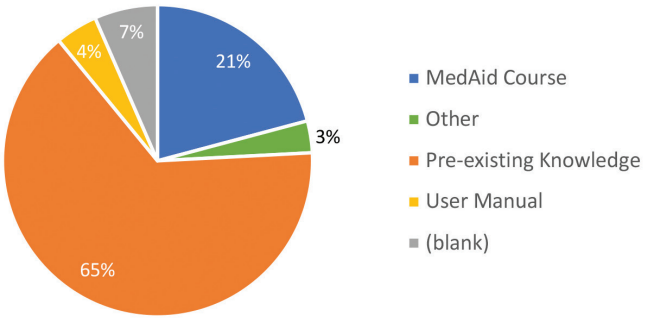
Resolution and Knowledge Source

The majority (65%) of maintenance solutions drew-upon pre-existing knowledge, with the MedAid Course accounting for 21% of all patient monitor maintenance solutions.

Various solutions, many derived from pre-existing knowledge and MedAid training, were implemented to resolve faulty patient monitors. Connection issues were resolved by correctly reconnecting or replacing BP cuffs subsequently resolving pressure problems and ensuring accurate BP readings. Replacement of components like motherboards, LCDs, and pumps from obsolete equipment helped fix non-functioning machines. Calibration tasks were performed as per user manual instructions, ensuring accurate measurements. Routine preventative maintenance, including cleaning, functionality tests, and part replacements were done in response to MedAid training. Specific issues like short circuits, glass shield breakages, and component failures (e.g., speakers, batteries, probes) were resolved by part replacements and repairs. The MedAid course particularly provided skills for preventative maintenance; handling circuit issues; and performing accurate calibrations, contributing significantly to the efficient resolution of equipment faults.

Figure 4.

Knowledge Source of Maintenance Solution



Oxygen Concentrators

Summary

The data on oxygen concentrators reveals a variety of faults and issues commonly reported by engineers. Preventative and planned preventative maintenance (PPM) tasks are the most frequently mentioned, indicating routine upkeep is a significant focus. Low oxygen purity and associated alarms are also prevalent, suggesting ongoing concerns with the efficacy of oxygen delivery. Faulty compressors, which are integral to the concentrator's function, are another common issue. Some devices fail to switch on, pointing to electrical problems. Specifically, issues with control board failures and burnt plugs are mentioned. Mechanical issues, such as broken humidifier bottles and leakage of tubing, also appear regularly. Additionally, specific issues with flowmeters and flowmeter regulators are reported, affecting the accuracy of oxygen delivery. There is also one instance of zeolite leakage. In total, 371 oxygen concentrators were logged in the equipment audit and 61 were recorded in the maintenance log.

Table 3. Primary Issues and Reported Frequency

EQUIPMENT FAULT/ISSUE	FREQUENCY
PPM	17
Low Oxygen Levels and Purity	15
Power Failures	6
Humidifier Fault/Failure	5
Flowmeter Fault/Failure	4
Faulty Compressor	3
None/Blank	3
Tubing Leakage	2
Sieve Bed Damage	2
Filter	1
Error 10000	1
Loose Screw	1
Burnt Top Plug	1
Total	**61**

Breakdown of Issues by Category

- **Maintenance and Calibration:** Preventative maintenance tasks are the most frequently mentioned, indicating the importance of routine upkeep to ensure the reliability and functionality of oxygen concentrators.
- **Oxygen Purity:** Low oxygen purity and associated alarms are common issues, highlighting a critical area of concern for ensuring patients receive the correct concentration of oxygen. Medical Aid International is acutely aware of this issue and supplies oxygen analysers to each healthcare facility.
- **Compressors:** Faulty compressors are frequently reported, underscoring the significance of this component in the concentrator's operation and the need for regular maintenance checks.
- **Electrical Issues:** Problems such as devices not switching on, control board failures, and burnt plugs are notable, indicating a need for reliable power management and electrical system integrity. These errors are likely due to unstable power grids and cross-continent voltage discrepancies of donated equipment.
- **Flowmeters:** Faulty flowmeters and fluctuating ball floats are regularly cited, affecting the accuracy and reliability of oxygen delivery.
- **Leakage and Mechanical Failures:** Issues with broken humidifier bottles, tubing leakage, and sieve bed leaks are common, pointing to physical wear and tear and the need for regular inspection and replacement of warn parts.

By addressing these recurring faults and implementing targeted maintenance strategies, the performance and reliability of oxygen concentrators can be significantly improved, ensuring better patient outcomes and more efficient healthcare delivery.

Table 4. Spare Parts Used in Maintenance Work

PARTS	FREQUENCY
Filters	6
Cables/Plugs	4
Humidifier Bottle	4
Control Board	1
Fuse	1
Tape	1
Tubing	1
Washing Powder[1]	1
Blower[2]	1
None/Blank	44

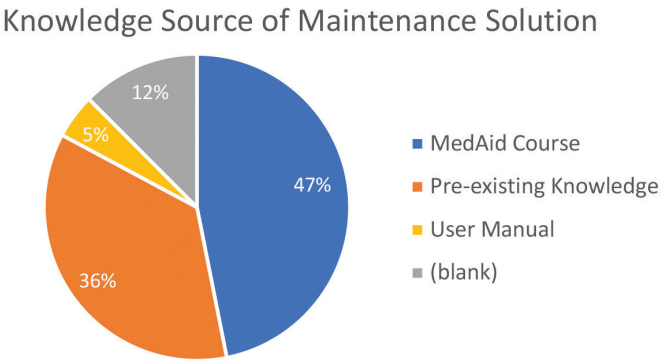
[1] Assume 'washing power' is some form of soap or detergent.
[2] Perhaps 'blower' refers to cooling fan.

Resolution and Knowledge Source

To address issues with oxygen concentrators, various solutions were applied. Flowmeter regulator issues were resolved by loosening screws, and dirty filters were cleaned to fix low oxygen alarms, utilising pre-existing knowledge. Faulty compressors and low oxygen purity often required troubleshooting and cleaning, while some issues necessitated replacing parts or components, these actions were accredited to knowledge gleaned from the MedAid Course. Maintenance typically involved changing filters and measuring oxygen purity, with successful outcomes attributed to MedAid training. Preventative measures included cleaning, dusting, and functionality tests, ensuring proper equipment performance. Some

complex issues, such as burnt plugs, faulty humidifier bottles, and circuit breakers, were managed using pre-existing knowledge and equipment manuals. The MedAid Course also guided practices like reconnecting tubing systems, moving machines for better airflow, and tightening loose parts, ensuring overall effective equipment maintenance and repair. Forty-Seven percent of the maintenance solutions were accredited to the Medical Aid International Online Biomedical Engineering Course.

Figure 5.



Suction Machines

Summary

The data on suction machines reveals several recurring issues. A significant number of machines are reported as not powering on or failing to switch on, indicating potential electrical problems. Low suction pressure is another common issue, often caused by blocked tubing, faulty motors, or other internal malfunctions. Preventative maintenance is frequently cited, highlighting the need for routine servicing to maintain functionality. Mechanical failures, particularly motor damage, are prevalent and affect the machines' operational capabilities. Kinked tubes are a major problem, significantly impacting suction performance. Additionally, there are reports of faulty components such as control boards, pressure gauges, vacuum jars, float valves, and canister seals. Issues like blown fuses and cleaning-related problems are also mentioned, suggesting that both electrical and maintenance aspects need to be addressed to ensure the reliable operation of these machines. In total, 263 suction machines were logged in the equipment audit and 48 were recorded in the maintenance log.

Table 5. Primary Issues and Reported Frequency

EQUIPMENT FAULT/ISSUE	FREQUENCY
Kinked Tube	12
No/Low Suction	10
Motor Fault/Failure	5
Not Powering On	5
Faulty Cannister Seal	4
PPM Conducted	4
Faulty Pressure Gauge	3
Damaged Float Valve	2
Broken Vacuum Jar	1
Aspirated[1]	1
Blank	1

[1] Suspect the entry suggests that the machine aspirated fluid from a patient past the collection jar and float valve and contaminated the internal pipework.

Breakdown of Issues by Category

- **Tubing Issues:** Kinked tubes are the most frequently reported problem, affecting the machine's ability to provide adequate suction.
- **Suction Performance:** Low suction pressure and failure to suction are the second most prevalent problems, often due to blocked tubing, motor damage, or faulty components. This problem was primarily resolved via cleaning, straightening kinked tubes, and changing the tubes.
- **Power Issues:** A frequent issue is machines not powering on, indicating potential problems with electrical components or the power supply.
- **Preventative Maintenance:** Regular preventative maintenance is highlighted, underscoring the importance of routine servicing to keep the machines operational.
- **Mechanical Failures:** Motor damage and issues with float valves, pressure gauges, and canister seals are noted, pointing to wear and tear or mechanical failures over time.

Table 6. Spare Parts Used in Maintenance Work

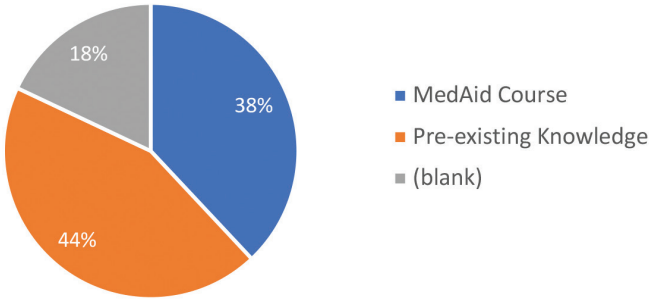
PARTS	FREQUENCY
Tubing	14
Seal	4
Pressure Gauge	3
Motors	2
Fiber	1
Filter	1
Float Valve	1
Fuse	1
Pipes	1
Pump	1
Sanitiser	1
Vacuum Jar	1
None/Blank	19

Resolution and Knowledge Source

To address various issues with suction machines, a range of solutions were implemented. Non-functioning machines often required fuse replacements in power cords, leveraging pre-existing knowledge. The MedAid course does also have a segment on fault finding and fuse replacement for those individuals who may not have this pre-existing knowledge. Preventative maintenance tasks, such as running functionality tests and decontaminating equipment, were guided by the MedAid Course. The course contains a module on safe decontamination and appropriate use of PPE while repairing equipment which is relevant for many of the suction machine jobs where fluid contamination has occurred. Low suction pressure and machine blockages were rectified by straightening kinked tubing, unblocking, and cleaning them, and providing user training, all based on MedAid training. Disassembling and loosening pumps to fix stuck motors, releasing stuck float valves, and replacing broken vacuum jars and faulty seals were also skills learned from MedAid. Complex repairs, like rewinding motor windings and replacing bacterial filters, were successfully completed, ensuring the machines were returned to proper working condition. The MedAid Course was instrumental in diagnosing and fixing issues, such as clogged filters, faulty pressure gauges, and creating appropriate suction pressure through tubing replacements and internal pipe changes.

Figure 6.

Knowledge Source of Maintenance Solution



Autoclaves

Summary

The data on autoclaves indicates a variety of recurring problems affecting their operation. Electrical issues such as blown fuses, power blockages, and tripping on overload relays are common, preventing the machines from starting or continuing their cycles. Mechanical problems are also significant, with frequent reports of door-related issues, including doors failing to open, door errors, and gasket leakages leading to pressure leaks. Heat failures and the machine not reaching sterilisation temperatures are notable problems, affecting the sterilisation process. Water leakage in the chamber, due to damaged components, is another failure type. PPM actions are mentioned rather infrequently; engineers should be reminded that regular servicing is an essential requirement for autoclaves. There are also instances of sensor malfunctions, such as temperature and water tank sensors failing, which impact the machine's ability to monitor and control the sterilisation process effectively. In total, 106 autoclaves were logged in the equipment audit, 42 were reported in the maintenance log.

Table 7. Primary Issues and Reported Frequency

EQUIPMENT FAULT/ISSUE	FREQUENCY
Failed Sterilisation	16
Leaks	*9*
Temperature Failures	*4*
Other	*3*
Electrical/Power Failures	11
Mechanical Failures	7
Door Faults/Failures	5
PPM	3

Breakdown of Issues by Category

- **Electrical Issues:** Common problems include blown fuses, power blockages, and tripping on overload relays, which prevent the autoclaves from operating correctly. Weak power grids may not be able to support the continuous high-power demand of autoclaves, leading to intermittent power interruptions and surges. These fluctuations can damage sensitive components within the autoclave, such as control boards and heating elements. Over time, this can result in a higher incidence of electrical failures and malfunctions, as the equipment is repeatedly subjected to inadequate or unstable power conditions. The prevalence of electrical issues and blown fuses reported in autoclaves is likely a reflection of these power challenges. Ensuring a stable and sufficient power supply can significantly reduce the frequency of electrical problems and improve the overall reliability and effectiveness of autoclaves.

- **Mechanical Failures**: Issues with door mechanisms, including doors not opening, door errors, and gasket leakages, are prevalent and significantly impact the machines' ability to maintain pressure and temperature.
- **Heat and Sterilisation Problems:** Heat failures and machines not reaching or maintaining sterilisation temperatures are critical issues that directly affect the sterilisation process.
- **Water and Steam Leakage:** Leaks in the chamber and around the door, often due to damaged valves or boiler vessels, are frequently reported and need addressing to ensure the autoclaves operate efficiently. Additionally, boiling water and pressurised steam pose serious danger to staff.
- **Sensor Malfunctions:** Faulty temperature sensors and water tank sensors can hinder the machine's ability to monitor and control the sterilisation cycle effectively.
- **Preventative Maintenance:** The need for regular preventative maintenance must be highlighted to prevent many of these issues occurrence and ensure the machines run smoothly. While many maintenance activities can be done by onsite engineers, the free-standing complex autoclaves may likely need yearly visits from equipment suppliers and technical experts. The small tabletop autoclaves do not require third party intervention.

Table 8. Spare Parts Used in Maintenance Work

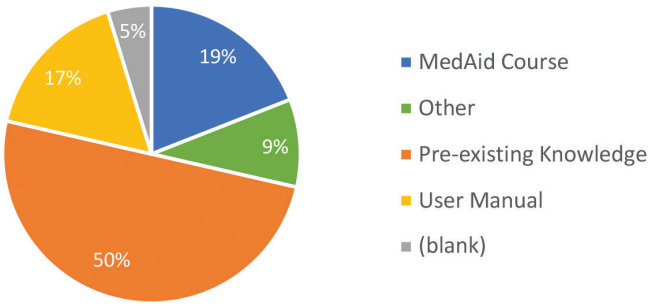
PARTS	FREQUENCY
Door Gaskets	7
Fuses	6
Solenoid Valves	4
Boilers	3
Heating Elements	2
Overload Relay	1
Power Board	1
Power Cable	1
Vacuum Pump	1
Water Sensor	1
Actuator Board	1
Door Motor Connectors	1
Door Sensor	1
None/Blank	14

Resolution and Knowledge Source

Medical Aid International's online course, tool kit, and textbooks were instrumental in learning circuit analysis and other key maintenance skills. MedAid's course emphasised the importance of regular cleaning and maintenance to prevent recurrent issues. Specific repairs and solutions accredited to knowledge gained from the Medical Aid International Online Course include replacement of a 230V fuse (supplied in MedAid toolkit) to resolve power blockage; replacing door gaskets to fix air leakages and ensure proper sealing; circuit analysis and subsequent reconnection for temperature sensors; and multiple instances of PPM, specifically cleaning.

Figure 7.

Knowledge Source of Maintenance Solution



Syringe Drivers/Infusion Pumps

Summary

Infusion pumps and syringe drivers, which are critical for delivering precise medication dosages, often face a range of issues. These problems include frequent screen failures; mechanical malfunctions, like broken spindle clamps; power issues such as blown fuses and machine start-up failures; system errors; and dangerous dosing errors. Proper maintenance and timely repairs are essential to ensure these devices function reliably and safely.

Table 9. Primary Issues and Reported Frequency

EQUIPMENT FAULT/ISSUE	FREQUENCY
Faulty Screen	10
System Error	5
Broken Spindle Clamp	4
Dosage Delivery Error	3
Failed To Power On	2
Blown Fuse	1
Occlusion Error	1

Breakdown of Issues by Category

- **Power and Electrical Issues:** Failure to switch on may indicate a potential power supply or internal circuitry problems.
- **System Errors/Software:** Frequent system errors indicate potential software or internal component issues that need diagnosing and fixing.
- **Display and Interface Problems**: Repeated instances of screen failures impede the ability to input settings and monitor infusions.
- **Mechanical Failures:** Mechanical failures like broken spindle clamps or occlusions in the tubing can prevent the device from properly securing and operating the syringe, affecting dosage delivery.
- **Dosage delivery:** Three specific instances of rapid dose delivery prior to the allocated time were recorded. This critical issue can lead to over-infusion, posing serious risks to patient safety and indicating a malfunction in the dosage regulation mechanism.

No PPM activities were recorded for syringe drivers/infusion pumps.

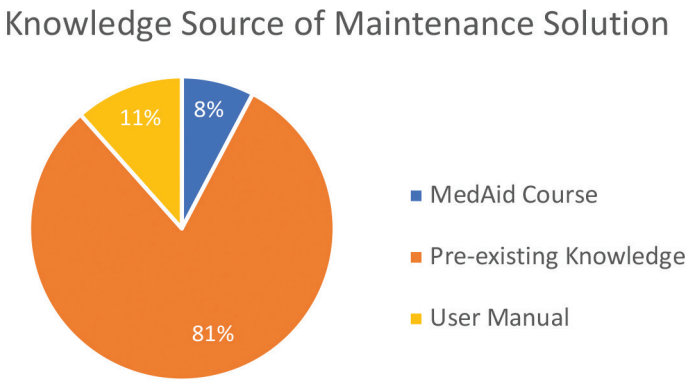
Table 10. Spare Parts Used in Maintenance Work

PARTS	FREQUENCY
Display Screen	9
Calibration Equipment	8
Power Cable	2
Spindle Clamp	4
Cleaning Cloth	1
None/Blank	2

Resolution and Knowledge Source

To address the various issues with infusion pumps and syringe drivers, several solutions were implemented primarily utilising pre-existing knowledge. Faulty screens were consistently resolved by replacing them with new screens, drawing on pre-existing expertise. Broken spindle clamps were also replaced, following guidelines in the equipment manual. Some of these parts had to be outsourced by local contractors. System errors and calibration issues were frequently addressed by cleaning sensors and recalibrating the machines, a process that relied on pre-existing knowledge. Problems like fast delivery of dosage were corrected by adjusting calibration settings. For power-related issues, such as blown internal fuses and non-functional machines, new fuses were installed, and power cables were replaced, often using parts salvaged from obsolete equipment—a solution derived from the MedAid course. Overall, the combination of equipment manuals, MedAid course learnings, and existing knowledge ensured that the infusion pumps and syringe drivers were effectively repaired and maintained.

Figure 8.



Ventilators

Summary

Ventilators commonly experience a variety of faults and issues, including problems compressor functionality, power supply issues, screen damage, disturbances in oxygen measurement, humidifier errors, test failures, internal battery failures, and faulty components such as flow sensors, oxygen sensors, and fuses. Additionally, error codes and system faults may occur, indicating issues such as short circuits or filter problems. Addressing these issues is critical for ensuring the reliable and effective operation of ventilators in medical settings.

Table 11. Primary Issues and Reported Frequency

EQUIPMENT FAULT/ISSUE	FREQUENCY
Faulty Sensors	7
Internal Battery Failure	4
Oxygen Measurement Disturbed	4
Inspection Failures	3
Misc. Error Codes	3
Faulty Filter	1
Broken Screen	1
Compressor Problem	1
Faulty Fuse	1
Burnt Power Supply	1

Breakdown of Issues by Category

- **Sensor Faults:** By far, the most reported issues involve faulty sensors (specifically oxygen and flow meter). Malfunctioning flow sensors can lead to inaccurate airflow measurements, affecting ventilator performance and patient care.
- **Test failures:** Test failures may indicate issues with ventilator performance or calibration, necessitating diagnostic testing and adjustments. PPM should be routinely conducted to prevent or identify such failures as early as possible.
- **Battery Failures:** Battery failures can compromise ventilator operation during frequent power interruptions or transport, highlighting the importance of battery maintenance and replacement.

Table 12. Spare Parts Used in Maintenance Work

PARTS	FREQUENCY
Flow Sensor	6
Oxygen Sensor	5
Battery	4
Test Lung	2
Fuse	1
Heater Wire	1
Humidifier	1
Diaphragm	1
Unknown	4
None/Blank	1

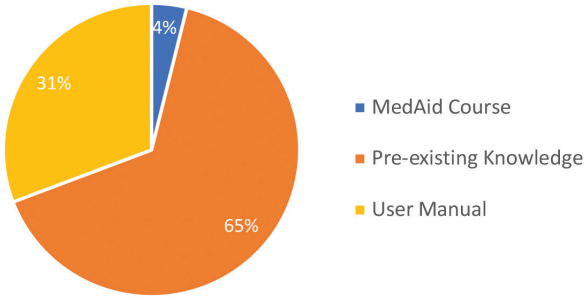
Resolution and Knowledge Source

To remedy the faulty ventilators, a variety of solutions were implemented, drawing primarily on pre-existing knowledge. Common issues like faulty flow sensors, compressor problems, and power supply burns were addressed by replacing the respective components, following guidelines outlined in the equipment manual. Issues with broken screens, oxygen measurement, and humidifier errors were resolved through component replacements. Spare parts for these tasks had to be sourced from local contractors. Test failures were rectified by replacing test lungs, while issues with expiratory tests were addressed by replacing diaphragm parts. Furthermore, internal battery failures were remedied through battery replacements, while faulty

oxygen sensors and fuses were also replaced successfully. The MedAid toolkit provides an assortment of batteries and fuses to assist in these situations. Dust inside the motor causing error codes was resolved through general cleaning techniques, once again highlighting the necessity of PPM.

Figure 9.

Knowledge Source of Maintenance Solutions



Anaesthetic Machines

Summary

Based on the data provided for anaesthetic machine faults and failures, the primary issues identified involve sensor failures, leakage, and display problems. Faulty oxygen sensors are the most frequent issue, with five instances reported. Expired oxygen sensors are also a concern, noted twice. Leakage is another significant problem. There are reported cases of air leaks from the oxygen concentrator; nitrous oxide leaks occurring inside the machine; and issues with the oxygen and nitrous valves not closing properly. Additionally, there are reports of low airway pressure and mechanical ventilator malfunctions, indicating potential problems with the delivery of anaesthesia. Broken components such as flowmeters and oxygen sensors further highlight the need for regular maintenance and prompt repairs. Display issues, including the monitor or display not switching on or responding, suggest that interface problems can hinder the usability of these machines. Overall, ensuring the reliability of sensors, preventing gas leaks, and maintaining functional displays are crucial for the safe operation of anaesthetic machines.

Table 13. Primary Issues and Reported Frequency

EQUIPMENT FAULT/ISSUE	FREQUENCY
Oxygen Sensor Failures	8
Oxygen Leaking	2
Monitor/Display Faults	2
PPM	2
Mechanical Faults	2
Ventilator Bellow	*1*
O_2 And Nitrogen Valves Not Closing	*1*
Component Failures	2
Broken Flowmeter	*1*
Flow Sensor and Software Upgrade	*1*
Nitrogen[1] Leaking	1
Insufficient Anaesthetic Agent Delivery	1
Low Airway Pressure	1
Blank	1

[1] Nitrogen gas is how nitrous oxide is referred to within the log.

Breakdown of Issues by Category

- **Sensor Failures:** Faulty and expired oxygen sensors are the most common issues, indicating the critical importance of sensor functionality in anaesthetic machines.
- **Leakages**: Multiple instances of gas leakage, including air, nitrous oxide, and oxygen, suggest that maintaining tight seals and properly functioning valves is essential. Anaesthetic machines are designed to deliver a precise mixture of gases to ensure effective anaesthesia. A nitrous oxide leak can disrupt the balance of gases, leading to inadequate delivery of anaesthetic agents. This can result in insufficient anaesthesia, causing patient awareness or inadequate sedation during surgery or hypoxia.
- **Display Problems:** Issues with monitors and displays not switching on or responding can significantly impact the usability of the machines.
- **Component Failures:** Broken flowmeters, faulty oxygen sensors, and mechanical ventilator issues point to the need for regular inspection and replacement of critical parts.
- **Preventative Maintenance:** There are relatively few entries indicating PPM actions. Anaesthetic machines require significant PPM to ensure safe optimal performance. Circle (closed-circuit) machines require considerably more regular replacement of consumables and PPM than most open-circuit machines if they are to remain in a safe and usable condition.

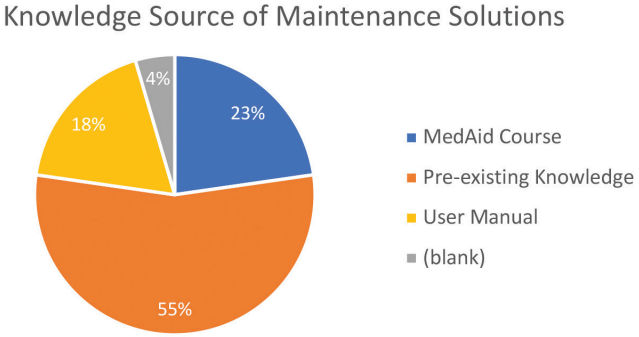
Table 14. Spare Parts Used in Maintenance Work

PARTS	FREQUENCY
Oxygen Sensors	8
Pipe/Pipe Connector	2
Display Monitor	2
Fibre	1
Valves	1
None/Blank	8

Resolution and Knowledge Source

To address the faulty anaesthetic machines, several solutions were implemented. The broken oxygen sensor was successfully remedied by replacing it, a skill acquired from the MedAid Course. When the display failed to switch on, the display monitor was replaced, utilising pre-existing knowledge. Similarly, the malfunctioning monitor or display was resolved by replacing it, with the solution learned from the MedAid Course. Nitrous oxide leaking inside the machine was addressed by changing the leaking pipe, the engineer referred to the equipment manual for guidance. For instances such as air leakage and expired oxygen sensors, solutions were applied based on pre-existing knowledge. Preventative maintenance procedures were conducted, including cleaning, decontaminating, and checking various components, with techniques learned from the MedAid Course. Furthermore, issues such as low airway pressure and faulty oxygen and nitrous valves were resolved through a combination of knowledge gained from the MedAid Course and pre-existing knowledge, utilising spare parts from other machines or workshop stores as necessary.

Figure 10.



Infant Incubators

Summary

The maintenance records of the Infant Incubators indicate a range of recurring issues and corresponding maintenance actions. Common problems include sensor disconnects, low and high temperature fluctuations, motor errors, power failures, and dusty conditions. These issues were addressed through various maintenance interventions, including part replacements, cleaning, calibration, and preventative maintenance. Spare parts were often sourced from workshop stores or other decommissioned equipment. Maintenance knowledge was acquired primarily through MedAid courses and pre-existing knowledge. In total, 80 infant incubators were logged in the equipment audit, 19 were recorded in the maintenance log.

Table 15. Primary Issues and Reported Frequency

EQUIPMENT FAULT/ISSUE	FREQUENCY
PPM	10
Low Temperature	4
Sensor Errors	3
Overheating	1
Not Powering On	1

Breakdown of Issues by Category

- **Maintenance**: Regular maintenance activities are essential for ensuring the continued functionality and reliability of infant incubators. Maintenance tasks include cleaning, calibration, and part replacement to address wear and tear. Nine out of 10 of these maintenance activities were accredited to knowledge gleaned from the MedAid Course.
- **Temperature Regulation Issues:**
  - **Low Temperature:** Instances of low temperature within the incubator have been observed, potentially compromising the ability to provide a stable and warm environment for newborns who are unable to regulate their own body temperature. Failure to sufficiently warm a newborn can result in serious harm or death.
  - **Overheating**: An incident of the incubator overheating has been recorded. Overheating can cause harm and fatal risk to infants.
- **Sensor Disconnect:** Occasional sensor disconnects have been reported, affecting the reliability of temperature, humidity, and oxygen monitoring within the infant incubator.

Table 16. Spare Parts Used in Maintenance Work

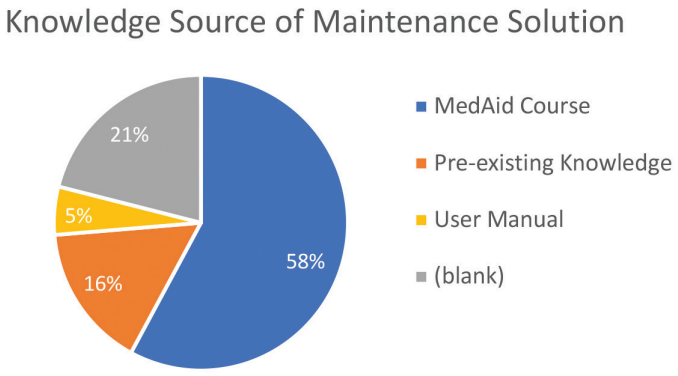
PARTS	FREQUENCY
Iris Port Covers	7
Air Filter	4
Gaskets	2
Detergent	1
Fuse	1
Blower[1] Motor	1
Oxygen Sensor	1
Relay	1
Cable	1
None/Blank	7

[1] Assume 'blower' in this instance means fan.

Resolution and Knowledge Source

To remedy the faults in the infant incubators, a variety of maintenance actions were undertaken, many of which were informed by the MedAid course. Sensor disconnects and general servicing were managed through routine machine servicing, ensuring all components were in optimal condition. Low temperature issues were resolved by closing air leakages with iris port gaskets, a technique learned from the MedAid course, with spare parts sourced from the workshop stores. One of the incubators with low temperatures was offline for 89 days before restored due to MedAid acquired knowledge. Overheating problems were fixed by repairing the fan based on user manual guidelines, without needing spare parts. Regular maintenance involved cleaning the incubators; replacing iris port covers and air filters; and checking temperature accuracy using external thermometers, all these procedures were taught in the MedAid course. For motor errors and power issues, the fan motor and power components were replaced, also drawing on MedAid training. Additionally, preventative maintenance was planned to keep the incubators dust-free and functioning efficiently. Knowledge from the MedAid course was instrumental in addressing most issues, ensuring the incubators were effectively serviced and repaired.

Figure 11.



Infant Radiant Warmers

Summary

The common faults and issues reported with infant radiant warmers include problems related to temperature regulation, power supply, machine booting errors, mechanical components, and general maintenance needs. These issues can compromise the functionality and safety of the equipment, impacting its ability to provide adequate warmth and care to infants.

Table 17. Primary Issues and Reported Frequency

EQUIPMENT FAULT/ISSUE	FREQUENCY
Power Supply	4
PPM	4
Machine Error	1
Broken Caster	1
Faulty Fuse	1
Faulty Temperature Sensor	1

Breakdown of Issues by Category

- **Power Supply:** Issues with the power supply can result in the radiant warmer not turning on or experiencing intermittent power failures, disrupting its operation and potentially endangering infants. Blown/faulty fuses can disrupt the electrical circuitry of the radiant warmer, resulting in power supply issues.
- **Temperature Regulation:** This issue can result in inaccurate temperature readings, posing a risk of overheating or inadequate warming for infants which can be fatal.
- **Mechanical Components:** Damage to the casters can impede the mobility of the radiant warmer, making it difficult to move or position as needed for patient care.
- **Planned Preventative Maintenance:** Scheduled maintenance tasks, including cleaning, lubrication, and component checks, are crucial for ensuring optimal performance and extending the lifespan of the equipment.

Table 18. Spare Parts Used in Maintenance Work

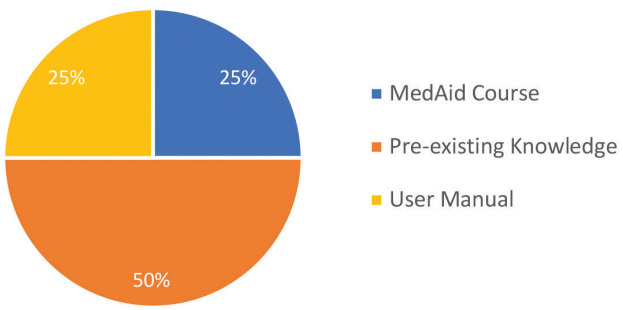
PARTS	FREQUENCY
Fuse	3
Cleaning Supplies	2
Caster	1
PCB Board	1
Power Switch	1
Temperature Probe	1
None/Blank	3

Resolution and Knowledge Source

Various faults in the infant radiant warmers were addressed through a combination of troubleshooting, part replacements, and preventative maintenance. Solutions ranged from replacing malfunctioning components, like the temperature sensor and control board, to conducting routine servicing and preventative maintenance as part of a proactive approach. Skills and knowledge gained from the MedAid course were particularly instrumental in replacing a broken caster and planning preventative maintenance tasks. Additionally, pre-existing knowledge coupled with access to the resources (tools and fuses) provided by MedAid, facilitated the successful replacement of faulty power switches and blown fuses. These efforts ensured the continued functionality and safety of the infant radiant warmers, highlighting the importance of both training and availability of resources in biomedical equipment maintenance.

Figure 12.

Knowledge Source of Maintenance Solution



Ultrasound Machines

Ultrasound machines, essential for diagnostic imaging, often face a variety of issues that can impact their performance and reliability. Common problems include power and start-up failures; issues with probes and transducers; mechanical problems like loosened parts; and the need for regular maintenance. Prompt identification and resolution of these issues are crucial to ensure the effective operation of ultrasound equipment in medical settings.

Table 19. Primary Issues and Reported Frequency

EQUIPMENT FAULT/ISSUE	FREQUENCY
Faulty Probes	3
Power Failure	3
Start-up Failure	*1*
Power Supply Failure	*1*
19v dc 8Am charger burn	*1*
Servicing	2
Faulty Transducer	1
Loose Part	1
Faulty Cursor[1]	1

[1] Most likely referencing the tracker-ball which controls the movement of the cursor.

Breakdown of Issues by Category

- **Power Failures:** Multiple instances reporting challenges with power were recorded. This may indicate potential issues with the power supply, charger, or internal electronics.
- **Probes/Transducers**: Faulty probes and transducers can affect the machines' ability to capture and display images. Malfunction may be caused by physical damage as accidental drops or impacts can damage the delicate crystals and electronics inside the probe or transducer; wear and tear; cabling issues, electronic failures, or improper use.
- **Mechanical Problems:** The mechanical issues with loose parts and the faulty cursor may be a result of general wear and tear on equipment and/or lack of PPM.
- **Servicing:** This is a critical step in ultrasound upkeep to ensure accuracy and reliability of the machine and prevent equipment failure.

Table 20. Spare Parts Used in Maintenance Work

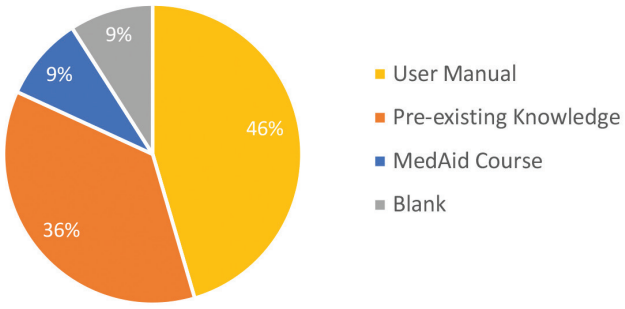
PARTS	FREQUENCY
Probe	3
Transducer	1
Power Cable	1
Fuse	1
Epoxy	1
Fiber	1
None/Blank	4

Resolution and Knowledge Source

To address the various issues with the faulty ultrasound machines, several solutions were implemented. Cleaning the tracker-ball, which had accumulated dirt and oil, was resolved using skills from the MedAid Course without requiring spare parts. Proper fitting of the ultrasound probe and rejoining parts with adhesive glue (epoxy) were successfully accomplished using pre-existing knowledge. Replacement of a blown fuse and a power cable were also managed with pre-existing knowledge. New transducers and/or probes were installed following instructions in the user manual, with the parts sourced from workshop stores or local contractors. Regular inspections, cleaning, and servicing of the machine, including the electronic board and body, were performed according to the user manual and completed successfully, sometimes involving external engineers. The machine with a burnt charger was unable to be repaired as no charger could be procured.

Figure 13.

Knowledge Source of Maintenace Solution



Pulse Oximeters:

Summary

Issues commonly encountered with pulse oximeters include problems with displaying parameters on the screen, power switch malfunctions, failure to show SpO_2 readings due to sensor issues, and errors related to sensor functionality. These faults can affect the accuracy and reliability of oxygen saturation measurements, compromising patient monitoring during medical procedures. Implementing preventative maintenance plans and conducting repairs are crucial for ensuring the proper functioning of pulse oximeters.

Table 21. Primary Issues and Reported Frequency

EQUIPMENT FAULT/ISSUE	FREQUENCY
Power Switch Failure	2
PPM	2
Screen Errors	2
Sensor/Probe Errors	2

Breakdown of Issues by Category

- **Power Switch and Functionality**: Malfunctioning power switches can prevent the pulse oximeter from turning on or off reliably, affecting its usability and reliability for patient monitoring. This broad issue encompasses difficulties with both powering the device on/off and problems with the screen display, indicating potential electrical or software issues.
- **Display and Parameter Reading:** This issue hampers the ability to view essential monitoring data, potentially leading to delays in diagnosis or treatment. Failure to display SpO_2 readings suggests a problem with the sensor connection or functionality.
- **Sensor Errors:** Sensor errors can arise due to issues such as poor sensor connection, damage, or signal interference, necessitating troubleshooting and corrective action.
- **PPM:** Implementing preventative maintenance plans including conducting regular inspections is essential for proactively addressing potential issues and ensuring the continued reliability and accuracy of pulse oximeters in clinical settings.

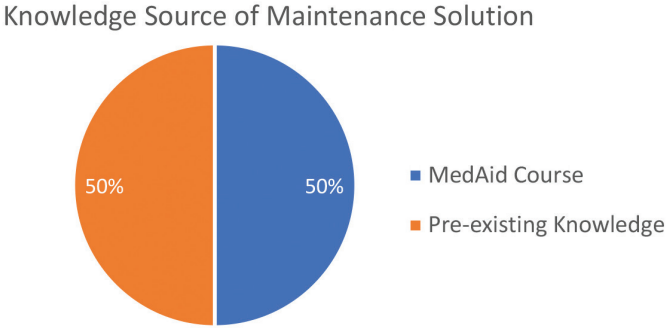
Table 22. Spare Parts Used in Maintenance Work

PARTS	FREQUENCY
Sensor/Probes	2
Power Switch	1
Cables	1
Fuse	1
Display Board	1
None/Blank	3

Resolution and Knowledge Source

To address various issues with pulse oximeters, a range of solutions were implemented. For instances where parameters were not displaying on the screen, changing the patient probe was an effective approach, this was an approach acquired from the MedAid course. Power switch malfunctions were resolved by replacing the switch, drawing from knowledge also gained from the course. The inaccessibility of spare parts prevented one hospital from rectifying their SpO_2 errors due to sensor problems. At another facility, replacement of faulty probes to address sensor errors, drawing from skills learned in the MedAid course, restored proper functionality. For more complex issues like on/off and screen problems, and non-functional switch buttons, repairs were undertaken with pre-existing knowledge which required soldering and cable replacement. Soldering kits were provided by Medical Aid International. In one such instance where significant repairs were made, guidance to clinical users was given to ensure that they knew how to use the highly modified part. The MedAid course puts significant emphasis on building skill to professional communicate with and train colleagues for instances such as this. Additionally, preventative maintenance plans were implemented based on training from the MedAid course, ensuring ongoing reliability and performance of the pulse oximeters.

Figure 14.



Surgical Diathermy/ESU

Summary

Surgical diathermies, critical for cutting and coagulating tissue during surgery, frequently encounter issues that can impede their performance. Common problems include power and start-up failures, issues with integrated circuits and boards, bipolar electrode faults, and loose electrode connections. Prompt identification and resolution of these issues are essential to ensure the reliable operation of diathermy equipment in surgical settings.

Table 23. Primary Issues and Reported Frequency

EQUIPMENT FAULT/ISSUE	FREQUENCY
Not Coming On	4
Faulty Integrated Circuit	1
Bipolar Electrode fault	1
Faulty Board	1
Loose Electrode Wire	1

Breakdown of Issues by Category

- **Start-up Failures**: Several instances occur where the equipment fails to power up, indicating potential issues with the power supply, internal wiring, or electronic components.
- **Component failures:** Malfunctioning integrated circuit led to inability to cut or coagulate which is crucial for the devices core functionality. Problems with the circuit boards affect overall operation of the diathermy.
- **Electrode Issues:** Issues specific to the bipolar electrode are possibly due to wear and tear or maintenance needs. Poor connectivity of the electrode wire can hinder the device's effectiveness and precision during procedures.

Table 24. Spare Parts Used in Maintenance Work

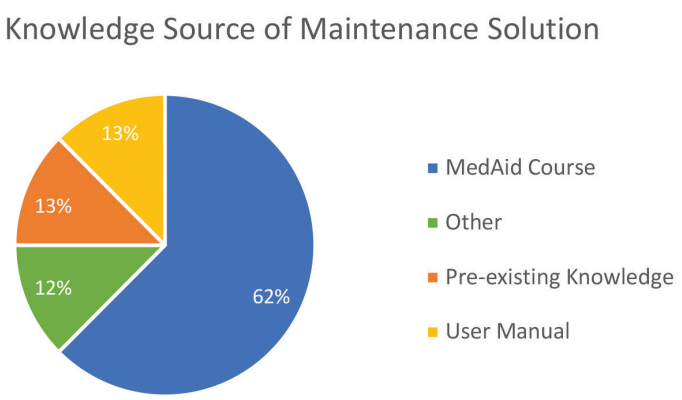
PARTS	FREQUENCY
Fuse	3
Integrated Circuit	1
Multimeter	1
Screw Drivers	1
Relay Switch	1
Board	1
None/Blank	2

Resolution and Knowledge Source

To remedy the faulty surgical diathermies, several targeted solutions were implemented, drawing primarily on skills learned from the MedAid course. The common issue of the start-up failure was consistently resolved by replacing blown fuses, a solution effectively learned from the MedAid course. Additionally, MedAid provided all engineers with an assortment of fuses. When the device failed to cut or coagulate due to a faulty integrated circuit, the circuit was replaced, with parts sourced from a local supplier. Voltage regulator issues were addressed using existing knowledge, involving the repair of relay switches and multimeter (supplied by Medical Aid International) diagnostics to restore functionality. Maintenance for

bipolar electrodes, which included general cleaning and soldering of cables, was successfully completed using techniques from the MedAid course. A faulty board was replaced following guidelines in the equipment manual with parts sourced locally. Lastly, loose electrode wire connections were fixed by carefully reconnecting the wires, a process that required caution and was informed by the MedAid training. Overall, these solutions ensured that the diathermy equipment was returned to reliable and functional use.

Figure 15.



Operating Room Tables

Summary

Operating room tables are essential for positioning patients during surgeries. Common issues affecting these tables include problems with motion, electrical failures, and malfunctions of specific features. Regular maintenance and timely repairs are crucial to ensure these tables remain functional and reliable.

Table 25. Primary Issues and Reported Frequency

EQUIPMENT FAULT/ISSUE	FREQUENCY
Motion Failure	3
Start-up Failure	1
Lock Malfunction	1
PPM	1

Breakdown of Issues by Category

- **Motion Problems:** These issues indicate potential problems with the hydraulic, mechanical, or electrical systems responsible for the table's vertical movement. Two of the three tables reporting motion failures were manual.
- **Electrical and Power Issues:** The often-unstable power supply, frequent power surges, and the use of donated tables with incorrect voltage can cause the electric components to fail, leading to failure.
- **Mechanical Issues**: Mechanical failures such as faulty gears or broken lock mechanism (essential for stabilising the table) can pose significant risk during surgical procedures.

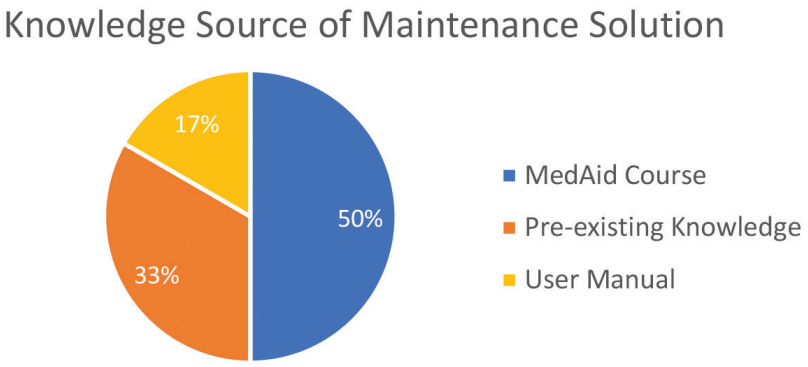
Table 26. Spare Parts Used in Maintenance Work

PARTS	FREQUENCY
Lubricant/Hydraulic Fluid	4
Remote Control	1
Cable	1

Resolution and Knowledge Source

To remedy the faulty operating room tables, various solutions were employed. For tables that failed to move up and down, solutions included adding hydraulic fluid, lubrication, and dust removal, all techniques were learned from the MedAid Course. The malfunctioning locking feature was resolved via guidance from the equipment manual and parts acquired from local contractors. A new cable solved the power issue with one of the tables.

Figure 16.



Conclusion

In an attempt to understand the greatest common challenges across the 13 items examined above, each fault was allocated a broader failure category. The results are in table below:

Table 27. Overall Failure Categories

FAULT CATEGORY	FREQUENCY
PPM	62
Faulty Probe/Transducer	50
Damaged Accessories	38
Power Supply Failure	35
Mechanical Error	34
Dysfunctional Sensors	34
System Failure	34
Display/Screen Faults	19
Seal Failure/Leaks	15
Low Oxygen Levels and Purity	15
Battery Failure	9
Heating Element Failure	9
Faulty Fuses	7
Electronic Component Failure	6
Motor Failure	5
Software Error	5
Faulty Compressor	4
Faulty Alarms	4
Grand Total	**385**

Aside from PPM, which is not an event requiring a corrective maintenance activity, faulty probes and transducers required the most maintenance attention. Probes, transducers, and sensors[1] all play a crucial role in data acquisition as they measure physical phenomena and convert them into signals that can be read and interpreted. The high instances of faulty probes, transducers, and sensors, implies a critical lack in ability to provide accurate patient diagnostics and monitoring.

The next most common failure mode is damaged accessories. As is evident from the pilot study report, accessories play a crucial role in healthcare management and are necessary for the optimal performance. Kinked tubes, broken BP cuffs, missing vacuum jars, dirty filters, etc., can dictate the difference between operational and non-operational equipment.

Power issues are the third greatest obstacle leading to significant downtime and impact on patient care. Weak and unstable power grids cannot appropriately support the healthcare system. There is a great need for robust power management and system reliability.

In order to ascertain the most frequently used parts, the entire maintenance log, spanning all thirty medical equipment items across all participating facilities, was analysed. The most frequently reported parts that were used to bring faulty equipment back online are listed in Table 28.

Calibration equipment was the most frequently listed item. However, one facility is responsible for all entries utilising calibration equipment. This same facility, a 1000-bed university teaching hospital in Accra, Ghana, is also responsible for all mentions of simulators, blood leak detectors, and test lungs. No other facility mentioned any type of calibration or test equipment. While calibration equipment is fundamental to the safe and effective optimisation of medical equipment, it does not remedy an equipment failure but rather identifies the fault.

There were 23 recorded instances of probes being to be replaced. The most replaced were SPO_2 probes. Filters and fuses were the next most frequently required parts used to repair faulty equipment.

Our experience shows that by implementing a comprehensive procurement strategy, using equipment specifically designed for the LMIC environment, the pressure on the supply chain for spare parts is greatly reduced. Indeed, our data consistently shows that old, donated equipment (no longer under manufacture and usually at the wrong voltage) is often supplied without the correct accessories – making the equipment almost unusable.

As part of our review process, considerations were given to improvements for future rounds. When conducting studies, there is inevitably an evolutionary process of refinement. Such improvements have already been actioned and include collecting data on items which could not be fixed (and the reason why), as well as investigating how the MedAid toolkit facilitated maintenance and repairs.

It is encouraging that when considering the source of knowledge used to repair faulty equipment, 44% of the maintenance log entries listed the MedAid Course (when excluding the outlier site 06GH and blank entries). This clearly demonstrates the on-the-ground impact of the MedAid Course, with its contribution to enhancing patient care.

[1] While dysfunctional sensors are in a category of their own, they have been lumped into the discussion along with probes and transducers as it may be tricky for participating biomeds to correctly distinguish between the three: we suspect significant crossover.

Table 28. Summary of All Parts Used

PARTS USED	FREQUENCY OF USE
Calibration Equipment	**26**
Probes/Transducers	**24**
Probe-SPO2	15
Probe-temperature	3
Probe-ECG	2
Probe-ultrasound	3
Transducer	1
Sensors	**22**
Oxygen sensors	14
Flow sensor	6
Door sensor	1
Water sensor	1
Filters	**19**
Air filters	8
Filters	1
oil filters	1
Ultra-filter	1
Fine particle filter	4
Bacterial filter	1
filter, unknown	1
Oil filter	1
Diesel filter	1
Fuses	**19**
Cleaning supplies	**19**
Cleaning cloth	15
Disinfectant/Detergent	4
BP cuffs	**18**
Tubing	**16**
Simulators	**15**
Valves	**15**
Cylinder valve	8
Valve	4
Solenoid valve	3
Display screens	**14**
Gaskets/Seals	**13**
Door Gasket	4
Gasket	4
Seals	5
Cables	**12**
Cables	2
Extension cable	1
Power cable	9
Batteries	**12**
PCB board	**8**
Iris port covers	**8**
Flowmeter	**6**
Bulbs	**5**
Spindle clamp	**4**
Humidifier	**4**
Blood gas analyser stimulator	**4**
Boiler	**3**
Electronic components	**3**
Capacitor	1
Electronic components	1
Integrated circuit	1
Motors	**3**
motor	2
motor windings	1
Pressure gauge	**3**
Pump	**3**
Pipes	**2**
Blood leak detector	**2**
Test lung	**2**
Spanners	**2**
Gas clip	**2**
Speaker	**2**
Power switch	**2**
Citric acid	**2**
Lubricant	**2**
Multimeter	**2**
Pipe connector	**1**
Vacuum pump	**1**
Collimator head	**1**
Overload relay	**1**
DDR3 Ram	**1**
Isolator	**1**
Diaphragm	**1**
Engine oil	**1**
Grease	**1**
Blower	**1**
Heater wire	**1**
Water puller pump	**1**
Pyrogen	**1**
Caster	**1**
Relay	**1**
Tape	**1**
Relay switch	**1**
Remote control	**1**
Vacuum jar	**1**
Rotor	**1**
Screw	**1**
Epoxy	**1**
Screw drivers	**1**
Float valve	**1**
Distilled water	**1**
Blower motor	**1**
Software update	**1**
Humidifier bottle	**1**
Air Hoses	**1**
None/Blank/NA	**157**
Grand Total	**504**

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