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COVID-19, a blessing in disguise: the experience of a Nigerian radiotherapy engineer

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ABSTRACT

The health technology sector of low- and middle-income countries (LMICs) is bedeviled by performance failures that make it a significant obstacle to effective patient healthcare interventions. The predominant factors behind the sector's poor performance have been identified as (a) inadequately trained technical personnel and (b) the unserviceable condition of medical equipment.

Past studies show that after adequate training, there is an increase in the proficiency of in-hospital biomedical engineers, but the studies have been limited to the maintenance job description of the engineers. We present a case study of the successful installation of sophisticated medical equipment by an in-hospital engineer to demonstrate that comprehensive training can also develop the installation expertise of local engineers. The installation, which is usually accomplished by the equipment manufacturer, was delegated to the trained in-hospital engineer due to the COVID-19 pandemic.

Furthermore, the bulk of medical equipment in LMICs is imported, which has led to an over-dependence of their health sectors on non-indigenous technology to the detriment of local alternatives and know-how. The World Health Organization estimates that 7 out of 10 sophisticated medical equipment imported by LMICs are unserviceable due to the issue of compatibility and adaptability with the setting. Previous research focuses on equipment subsidy, frugal innovation, and health technology management to better adapt foreign equipment to the environment. Still, this paper explores the option of indigenous technology and expertise to provide in-country development of suitable and sustainable medical equipment.

Keywords – *COVID-19, medical equipment, engineer, LMIC, training, installation, local production.*

INTRODUCTION

As the world's nations grappled with the COVID-19 pandemic, several unprecedented measures were adopted to limit the spread of the disease. Social distancing, quarantines, flight restrictions, lockdowns, and other routine-disrupting changes were imposed by governments at all levels.

On the 21st of March 2020, Nigeria went into lockdown, and restrictions were introduced on travel by land and air.[1] This, however, had only a partial impact on hospital activities because health workers, as essential service providers, were exempted from the restrictions. Doctors, nurses, and other hospital personnel kept working to provide medical care and manage the increasing patient volume due to coronavirus. Treatment of the disease required many types of lifesaving medical equipment, especially in intensive care units; therefore, more than ever, clinical engineers were needed to ensure the uninterrupted operation of medical devices.[2]

The job function of clinical engineers includes equipment maintenance, acceptance testing, user training and education, clinical research and development, quality assurance, and productivity assessment.[3] It is important to note that clinical engineering began in the late 1960s to address patient-safety concerns as increasing numbers of medical devices deployed in teaching hospitals. Not long after that, a preponderance of electrical safety failures brought the maintenance job description of in-house engineers to the fore.[4]

Clinical engineers develop their maintenance and troubleshooting skills through a combination of a hands-on learning experience, in-service training, and short courses designed to equip them with the skills to handle a wide range of medical devices. However, when hospitals acquire new or sophisticated technology with maintenance requirements beyond the engineer's general skills, maintenance contracts are signed, or equipment-specific training is sought. Hospitals typically opt for maintenance contracts with the original equipment manufacturers (OEMs) or their agents in high-income countries. On the other hand, hospitals in low- and middle-income countries (LMICs) opt for training because of the long distance between them and the OEMs.[5]

Unfortunately, the equipment-specific training is adequate on most occasions, and the hospitals are forced to resort to high-priced maintenance programs that still involve the OEMs or their third-party agents.[3,6] The local engineers are authorized to carry out only run-of-the-mill repairs while the heavy-duty maintenance is performed by the OEMs, usually after long waiting periods with a likelihood of poor treatment outcomes for the patient.[7]

Delay in cancer treatment leads to increased patient distress, increased risk of local recurrence, and reduced patient survival over time.[8,9] In LMICs, where delayed treatment is common, it can be attributed to late presentation in patients, inadequate radiation therapy facilities, insufficient trained manpower, and machine downtime.[10,11] Therefore, the goal of the in-house engineer is to minimize downtime so that patients can avail themselves of the already limited therapy units.

A previous paper has shown that with adequate training, in-house radiotherapy engineers (RE) could develop improvisation skills to reduce machine downtime in a Nigerian radiotherapy center.[12] This paper is a case study that shows that in-house RE can go beyond the usual maintenance tasks to installing sophisticated equipment that preserves OEMs and their agents with comprehensive training. However, it is worthy of note that the case study could not have arisen but for the advent of COVID-19.

A SUCCESS STORY

Before the COVID-19 lockdown, High Dose Rate (HDR) brachytherapy equipment was set for installation in four radiotherapy centers across Nigeria. The equipment, a 25-channel Saginova HDR After loader Brachytherapy system (Figure 1) manufactured by Eckert & Ziegler BEBIG GmbH Germany, had been shipped in, and engineers from the company were scheduled to follow for the installation work when the pandemic struck, and a restriction was placed on traveling.

As travel restrictions lingered, the situation became worse because, at the time, the country had only one functional brachytherapy center for its growing number of oncology patients. Moreover, the delay grew costlier with each passing day as the cancer cases worsened from lack of treatment and the radioactive decay of the expensive Co-60 sources.[13,14] It was therefore imperative to find a quick solution.

FIGURE 1. A 25-channel Saginova HDR afterloader brachytherapy unit installed by the local engineer.

The equipment manufacturer reached out to an RE in the Radiation Oncology Department, University College Hospital Ibadan (UCH), who had undergone training at their company factory (Figure 2). The training was sponsored by UCH after installing the same brachytherapy equipment in the hospital by the manufacturer in 2019.

The training

The five-day course gave the trained technical specialists level A and level A+ proficiencies. For example, the level A certification authorized them to carry out standard maintenance and basic interventions on the equipment as advised by the manufacturer, while the level A+ certification authorized them to load and unload radioactive sources.

Each trainee was provided with a full-color illustrated manual containing step-by-step information on how to unpack the equipment, install it, test it while inactive, load the Co-60 source, test it while active, and adjust the equipment settings. It also included schematic and circuit diagrams and layout diagrams of the standard control and treatment rooms. The teaching method employed was hands-on learning, where trainees first observed the instructors and then practiced the lessons. Common real-life faults were simulated, and the trainees were instructed on how to solve them.

Each training module ended with a Q and A and a quiz to test for mastery of the module. The trained and authorized engineers were then awarded certificates of training.

The installation

The RE successfully installed the equipment, loaded the Co-60 source, and conducted acceptance testing in the four radiotherapy centers (Figure 3). Barring the occasional logistic problems, the installation was uneventful and did not lead to problems the German engineers would not have encountered, such as broken cables and a damaged SafeLogic compact arising from inadequate packaging.

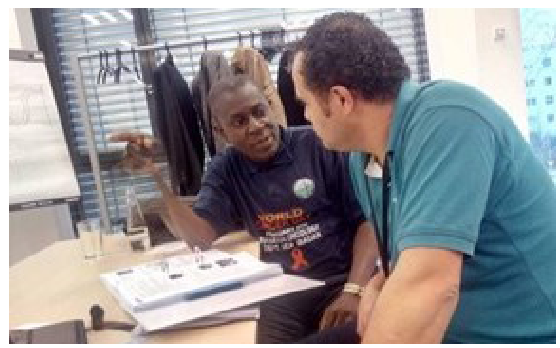

FIGURE 2. The radiotherapy engineer at the training facility in Germany.

The OEM provided remote guidance throughout the installation process, and the equipment was installed and handed over to the centers in good time. The RE also worked with the resident medical physicists to ensure that all technical parameters of the equipment were within acceptable limits.

The trainee becomes a trainer.

Before embarking on the training, the goal of the RE was to be reasonably proficient in maintaining the equipment in his center and other centers in the country that may require his service. In addition, having witnessed the long waiting periods that LMIC hospitals are subjected to when working with OEMs and agents, he planned to become an alternative service engineer with the least response time. This desire was made known to the trainers, and they provided as much instruction as possible within the limited training period.

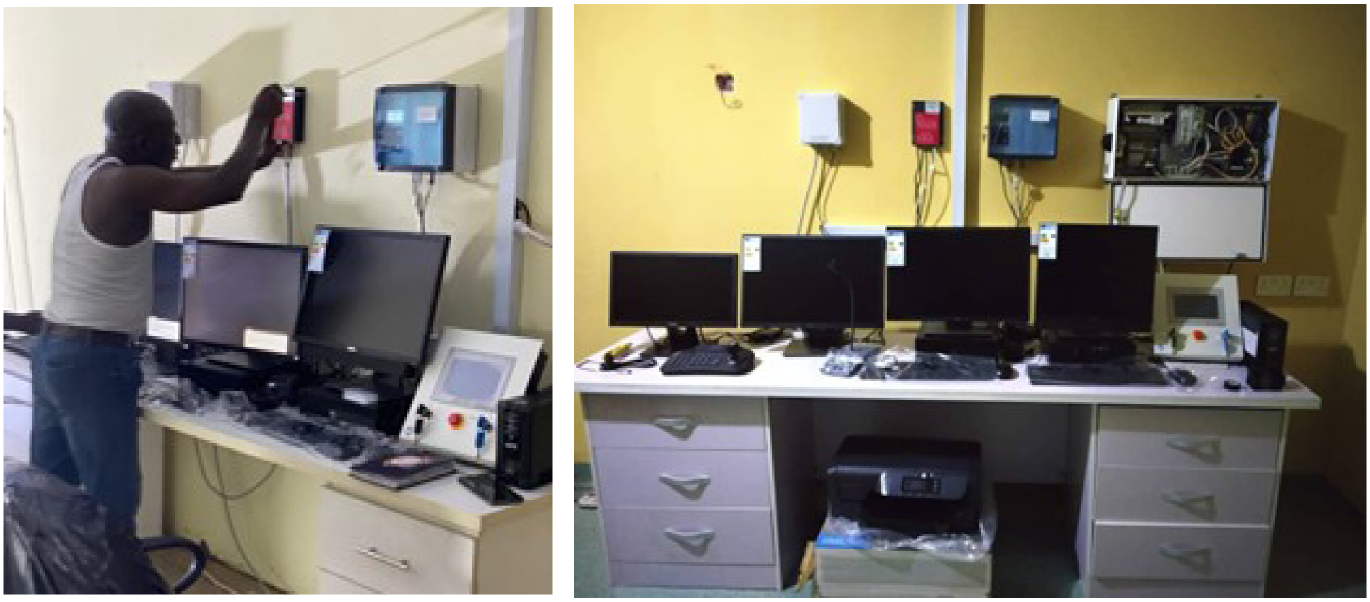

FIGURE 3. Setting up a treatment console (left). A fully installed treatment console (right).

However, the engineer's goal was flawed because it took up to two days to arrive at some centers, and if he were their service engineer, the equipment would be out of order for that long. Consequently, he rethought his plan and decided to train the centers' in-house engineers as much as possible so that they could independently maintain their equipment.

One center sponsored their engineer to join in installing the equipment of another center after participating in the installation at his center. The aim was to use the opportunity to further hone the expertise of their engineer.

BENEFITS ENJOYED FROM THE SUCCESSFUL INSTALLATION

Asides from the obvious benefits of timely brachytherapy treatment for cancer patients and obtaining value from the expensive Co-60 source, installing the equipment by a local RE had significant economic benefits for the hospitals. The two-way airfares for OEM engineers were eliminated, and the per diem was considerably reduced, saving the government some foreign exchange earnings. In addition, the experience boosted morale and increased the technical skills of the RE and his colleagues. It also gave him the expertise for guiding the prepurchase and procurement planning process of medical equipment in his department.

Finally, the trip to other radiotherapy centers helped develop a strong collaborative relationship between the RE and the in-house engineers of the centers.

LOOKING AHEAD

The healthcare needs in LMICs are tremendous, as is the quantity of medical equipment required to meet them. However, the bulk of medical equipment in these regions is imported or supplied by foreign donors. For example, a survey of 1,242 equipment in ten Indonesian hospitals revealed that only 4.2% were manufactured in that country.[15] The figures for Nigeria show the country is dependent on importation for about 99% of its medical equipment needs, and the small local production in the country is limited to simple devices like syringes. Regrettably, the impact of the country's $170m medical equipment market on patient care is still underwhelming as large numbers of imported medical equipment are unusable.[16]

Up to 70% of sophisticated medical equipment imported into LMICs is nonfunctional because of a mismatch between the equipment design and the setting where they are used. These "off-the-shelf" products fail to meet the environmental profile needs of LMICs already suffering from an unstable power supply, lack of clean water, an abundance of dust, and a hot and humid climate.[17] Even when the equipment is stripped down, they are still not explicitly designed to meet the 4 As for preventing equipment mismatch to a market: availability, accessibility, appropriateness, and affordability.[18]

In view of the above, LMICs should begin exploring the local production of low-resource medical equipment, starting with non-complex ones. Such equipment would be designed with the environmental profile in mind and consider practitioner/end-user input to meet the appropriateness factors. It would be made from locally available raw materials and stripped of nonessential features to solve availability and affordability problems.[19] However, this option remains only an aspiration until the many barriers facing local production are surmounted.

One of the principals but unintended barriers is the influx of donated foreign medical equipment. Low cost or donated medical equipment leads to aid dependency in LMICs and a stifling of the country's development.[20] Another barrier is the absence of an atmosphere conducive to R&D and innovation in LMICs.[18] R&D is funded mainly by industries in high-income countries, but in LMICs it is publicly funded through academic institutions. However, in Nigeria, for example, the better part of the time and activity of universities is devoted to teaching and assessing students, while research work is a secondary activity. Reasons like poor funding, insufficient research personnel, extraneousness of research focus on societal needs, and a delink between the academia and productive sectors have been attributed to the situation.[21]

To reverse this trend, the government needs to reappraise its allocations to the education sector, where the 2021 expenditure on salaries and overhead is 429% of the capital budget of the Federal Ministry of Education.[22] It also needs to double the funding for the Federal Ministry of Health to meet its 2011 Abuja Declaration of committing at least 15% of the annual budget to the health sector.[23] The two ministries and the Federal Ministry of Science and Technology must also work together to midwife the all-important collaboration among academic institutes, medical practitioners, and industries to kick off the production of domestically-designed medical equipment from locally-sourced raw materials for use in the nation's hospitals.

Other challenges that must be addressed before local production can begin in LMICs include establishing a regulatory framework for health technology assessment, harmonization of device classification, standardization for product safety and quality, and creating an enabling business environment. [23]

In-house hospital engineers can also contribute their quota to the local production of medical equipment in LMICs through additive manufacturing. A few hospitals have pioneered 3D printing laboratories for the fabrication of person-specific needs that are not on the market. These so-called hospital factories use additive manufacturing to make products like individualized prosthesis for patients and anatomo-functional models used for surgical planning and patient education.[24] Other areas where 3-D medical printing is used include the production of microfluidic devices for laboratory test, meal assistance devices for spinal cord injury patients, immobilization devices for radiotherapy and fixation plates implanted by orthopaedics surgeons.[25-27] Hospitals in LMICs can equip their biomedical engineering departments with 3-D printing labs to fabricate some of these personalized medical products.

The essence of locating the laboratory in the hospital is to foster collaboration between medical practitioners, patients (end users), and the engineers from the designing to production stages. While setting up the lab may be initially cost-intensive, hospitals can recoup their investments with a good business model, and patients can get apropos service at a fraction of the cost of getting it from OEMs.

CONCLUSION

Achieving adequate health technology in LMICs is long and fraught with many difficulties. Progress in the sector has come in fits and starts and has barely made a dent in providing healthcare facilities with the resources they need to provide patients with the care they need. But with a strategic plan to develop the local 'man and machine' and an unflinching determination to commit time and financial resources to the plan, LMICs too can begin the journey towards self-sufficiency in their practice of medicine.

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