Why do medical LINACs fail? A comparative analysis of radiotherapy provision in the UK and Africa

L. M. Wroe* [1], S. L. Sheehy [1] & F. Van den Heuvel [2]

[1] *John Adams Institute, University of Oxford, Keble Rd, Oxford, OX1 3RH, UK (* laurencewroe@gmail.com)*

[2] *Department of Oncology, University of Oxford, Roosevelt Drive, Oxford, OX3 7DQ, UK*

Introduction

- Radiotherapy is a critical component for treating and relieving the symptoms of cancer and is beneficial in half of all cancer cases[1]. Low- and Middle-Income Countries **(LMICs)**, however, have inadequate or, in many cases, no radiotherapy centres.
- It is argued by Coleman[2] that, for reasons of safety and security, a newly designed linear accelerator **(LINAC)** that suitably operates in an LMIC environment could address the cancer burden in LMICs.
- A CERN-STFC-ICEC led collaboration has established a technological and software task group to investigate the design of the new LINAC.
- This study looked at LINAC log books from radiation therapy centres in the UK (HIC), Nigeria (LMIC) and Botswana (LMIC) to determine how the challenges of an LMIC environment affect the performance of current generation LINACs. The conclusions made can then direct the task group on LINAC subsystems that need an urgent redesign.

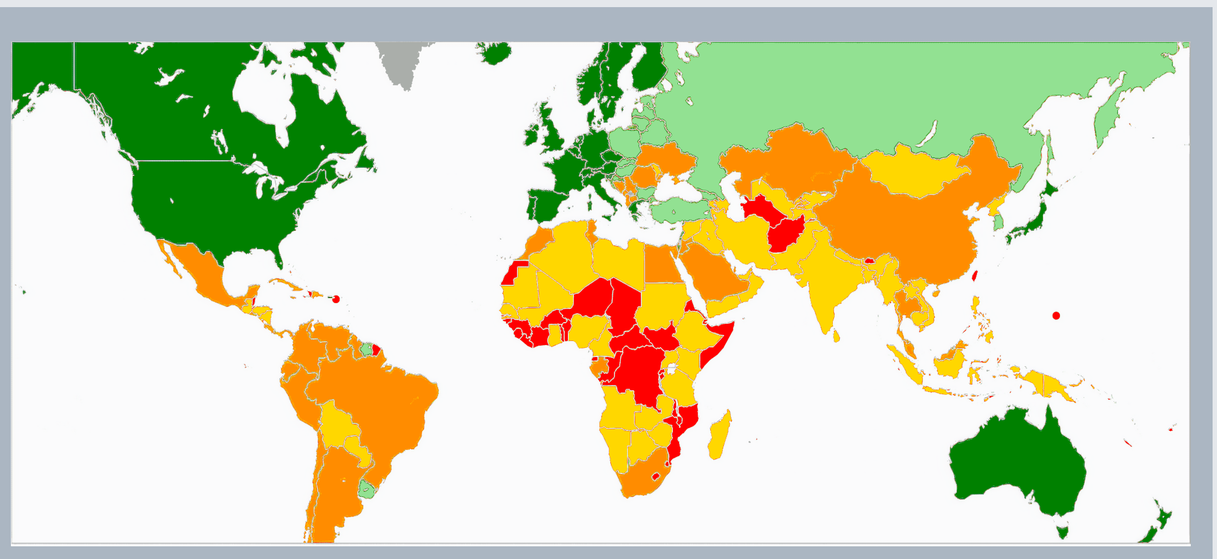

Fig. 1: Radiotherapy Machines per Million Population.

5 and more | between 3 and 5 | between 1 and 3 | less than 1 | no machine | no data

Data obtained from the IAEA's Directory of Radiotherapy Centres (DIRAC) database. https://dirac.iaea.org/

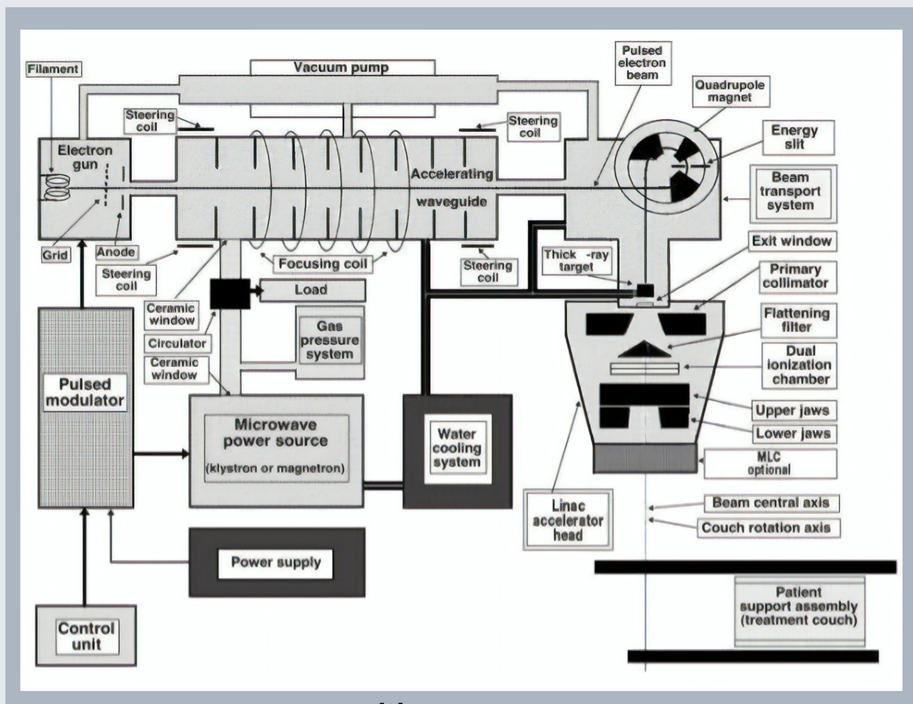

Fig. 2: LINAC diagram [3].

Method

- The LINACs studied do not record or log their own performance. As a result, log books kept by radiotherapy personnel were studied to assess LINAC performance and were obtained for 14 LINACs (6 in Oxford, 6 in Nigeria and 2 in Botswana).
- It was determined that the faults that cause the majority of downtime were the less frequent but more severe faults. Therefore the data was sampled to a manageable size by only studying faults that cause more than an hour of downtime.
- The LINAC was separated into 12 subsystems. Each fault from the sample was placed into one of the subcategories and assigned one of 7 fault causes.

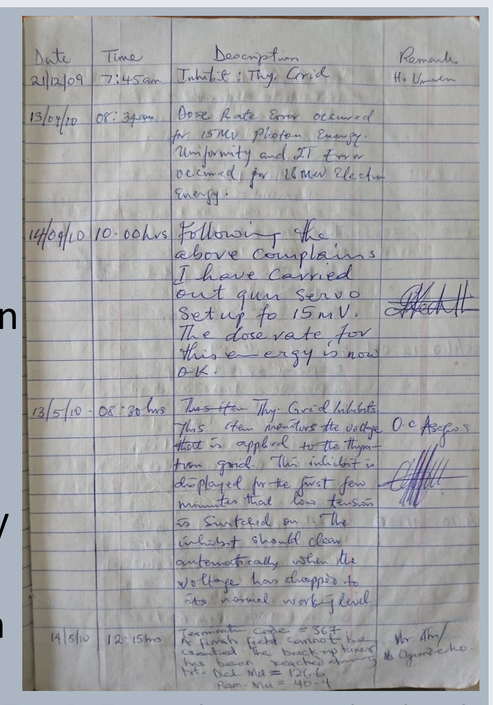

Fig. 3: Example page in log book.

Results

- As Fig. 4 shows, large periods of downtime are due to contextual issues, which include waiting for replacement parts, waiting for specialist engineers, and administrative procedures. These are hugely important factors affecting the delivery of radiotherapy treatment in LMICs and must be addressed.
- However, in order to achieve our aims of analysing how LINAC performance differs between environments, we must analyse the data independently of these contextual issues. Fig. 5 and Fig. 6 explore this by comparing the failure rate of the LINAC subsystems between the HIC and the two LMICs.
- Differences in the way that data is recorded in log books, the fact the LINAC models studied vary between the centres and the assumptions made to calculate failure rates, means care must be taken to draw fair conclusions.
- Fig. 5 and Fig. 6, however, show that there are no vacuum failures in the HIC but over 0.5 faults per 1000 hours of uptime in the LMIC. This difference in failure rate appears due to power instabilities in LMICs and is a key find of the study as vacuum failures can cause weeks of downtime.
- This preliminary study also indicates that the air, cooling and generator, computing, couch and door, gun and RF power subsystems have failure rates that differ significantly between the HIC and LMIC environments. It appears that the task group should focus on these subsystems in a redesign.

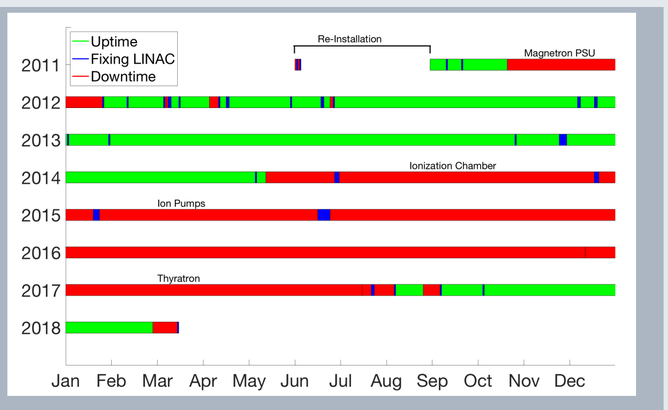

Fig. 4: Downtime in Enugu, Nigeria.

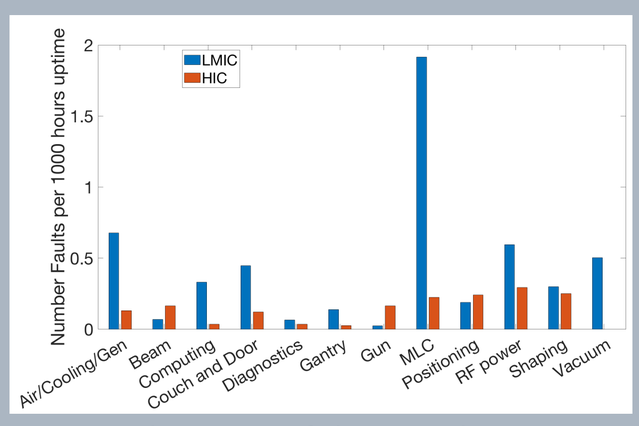

Fig. 5: Failure rate of the 12 subsystems.

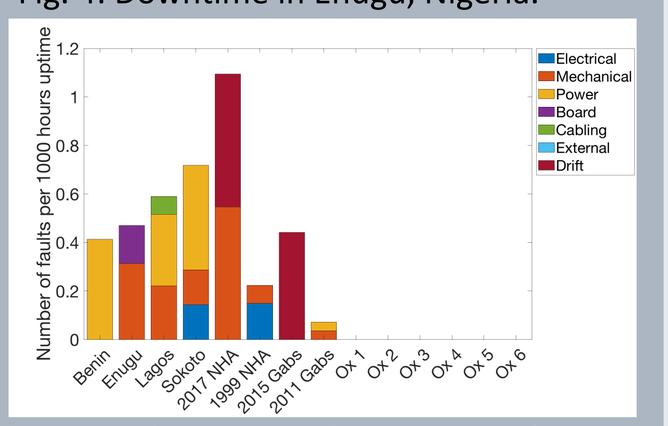

Fig. 6: Failure rate in the vacuum subsystem.

Future Work

After returning from Africa and analysing the data, the results were presented and subsequently discussed with senior figures in the CERN-STFC-ICEC collaboration. It was recommended that:

- This study is continued and the results and conclusions acted upon. It should also be expanded by collecting further LINAC data from more centres that use different machines.
- A standardised database is designed and shared with radiotherapy centres. This would allow a more direct comparison between LINACs in different environments and can allow for 'live' fault analysis and support.

A detailed report has been written and can be obtained by contacting laurencewroe@gmail.com.

Acknowledgements

Special thanks go to my supervisors, Dr Suzie Sheehy and Prof Frank Van den Heuvel, and the staff at the National Hospital Abuja, the Gaborone Private Hospital and the Churchill Hospital, Oxford.

This project was completed thanks to the Laidlaw Undergraduate Research & Leadership Programme at the University of Oxford.

Laidlaw Scholars
Undergraduate Research and Leadership Programme

References

1.M. Barton et al., *Estimating the demand for radiotherapy from the evidence: A review of changes from 2003 to 2012,* Radiotherapy and Oncology, 112 (1), **2014**

2. N. Coleman et al., *Treatment, not terror,* Journal of Global Oncology, 3 (6), **2017**

3. E. Podgorsak, *Radiation Physics for Medical Physicists,* Springer-Verlag Berlin Heidelberg, **2006**