A rethink of the linear accelerator for resource-limited environments

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AAPM Session on Affordable Cancer Care for All

Cancer is growing global challenge

- Globally **18** million new cases per year diagnosed and **9.6** million deaths in **2018**
- Will increase to **27.5** million new cases per year and **16.3** million deaths by **2040**
- **70% of these deaths** will occur in low-and-middle-income countries (LMICs)

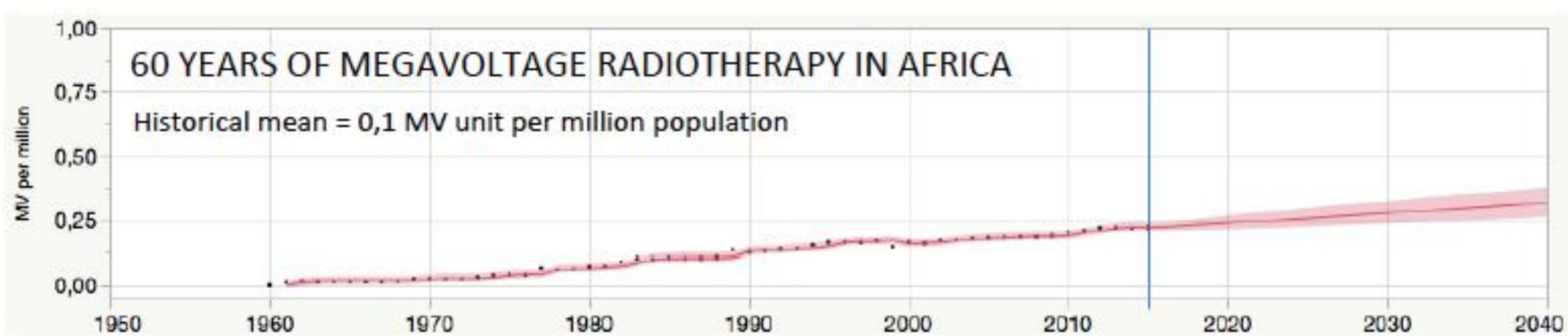
Radiation therapy is a key tool for treatment for over 50% patients and number of patients is increasing

LMICs have limited radiotherapy access: **Only 10% of patients in low-income** and **40% in middle-income countries have access to RT**

RADIOTHERAPY IN AFRICA

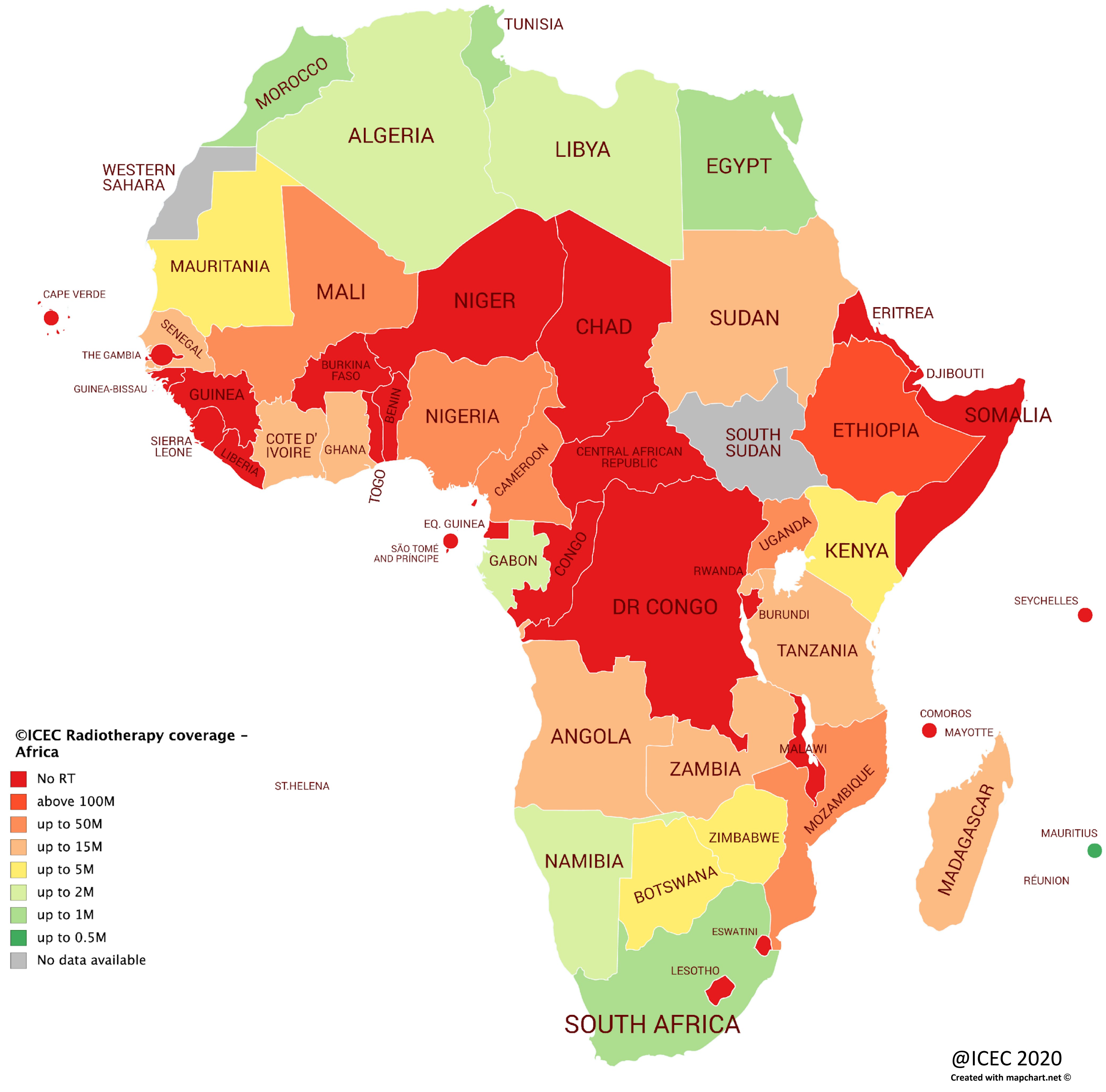
21 countries with RT in 1995

23 countries with RT in 2017



Dramatic Disparity in Access to Radiation Therapy Treatment

Country	LINACs	Population	People per LINAC
Ethiopia	1	115 M	115,000,000
Nigeria	7	206 M	29,000,000
Tanzania	5	59.7 M	11,900,000
Kenya	11	53.9 M	4,890,000
Morocco	42	36.9 M	880,000
South Africa	97	59 M	608,000
UK	348	67 M	195,000
Switzerland	72	86 M	119,000
US	3827	331 M	87,000



Map showing the number of people per functioning machine in countries in Africa

Africa’s Radiation Therapy Status

- **Acute shortage of RT** services both in quantity and quality
- **385 LINAC-**RT machines for more nearly **1.2 billion** inhabitants
- If current trends persist, GLOBOCAN forecast
  - By 2030, there will be **1.4** million new cases of cancer
  - and there will be **1** million deaths in Africa
- Only **28** countries have RT facilities **27** have none
- Over **60% located in just 3 countries**: South Africa, Egypt and Morocco
- **12** countries only one facility
- More than **18 countries** have Cobalt machines
- Africa has around **88 Co-60** machines (half of which are over 20 years old) proportionally more than any other continent
- Some of the **27 African countries lacking a Linac-RT** will consider buying Co-60 machine they are currently cheaper and easier to use

CHALLENGES

- Acute Shortage of RT services both in quantity and quality in AFRICA especially in ECOWAS (15 Member States)
- Only 5 (+1) Member States (CIV, GHA, MLI, NIR , SEN) currently have RT machines. TOGO commissioned a new LINAC just last month in a Private facility.
- BKF and NIG have made progress with building (bunkers) infrastructures
- LINAC technology requires strong, robust and reliable infrastructure (power, clean water, supply chain etc.) to operate and often difficult to access.
- Paucity of properly trained personnel's – resulting in both internal and external brain drain.
- LINAC servicing can be slow and very expensive. Service contracts are expensive and often not always purchased – Long down times (months or more).

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AFRICA’S ENVIRONMENT

Situation Today

Rapid machine failure and long down time

- End – of – Life machines
- Delay in spares funding approval and shipment

Increasing cancer care demands

- Machines not adequate to meet demands
- High cost of care
- High mortality

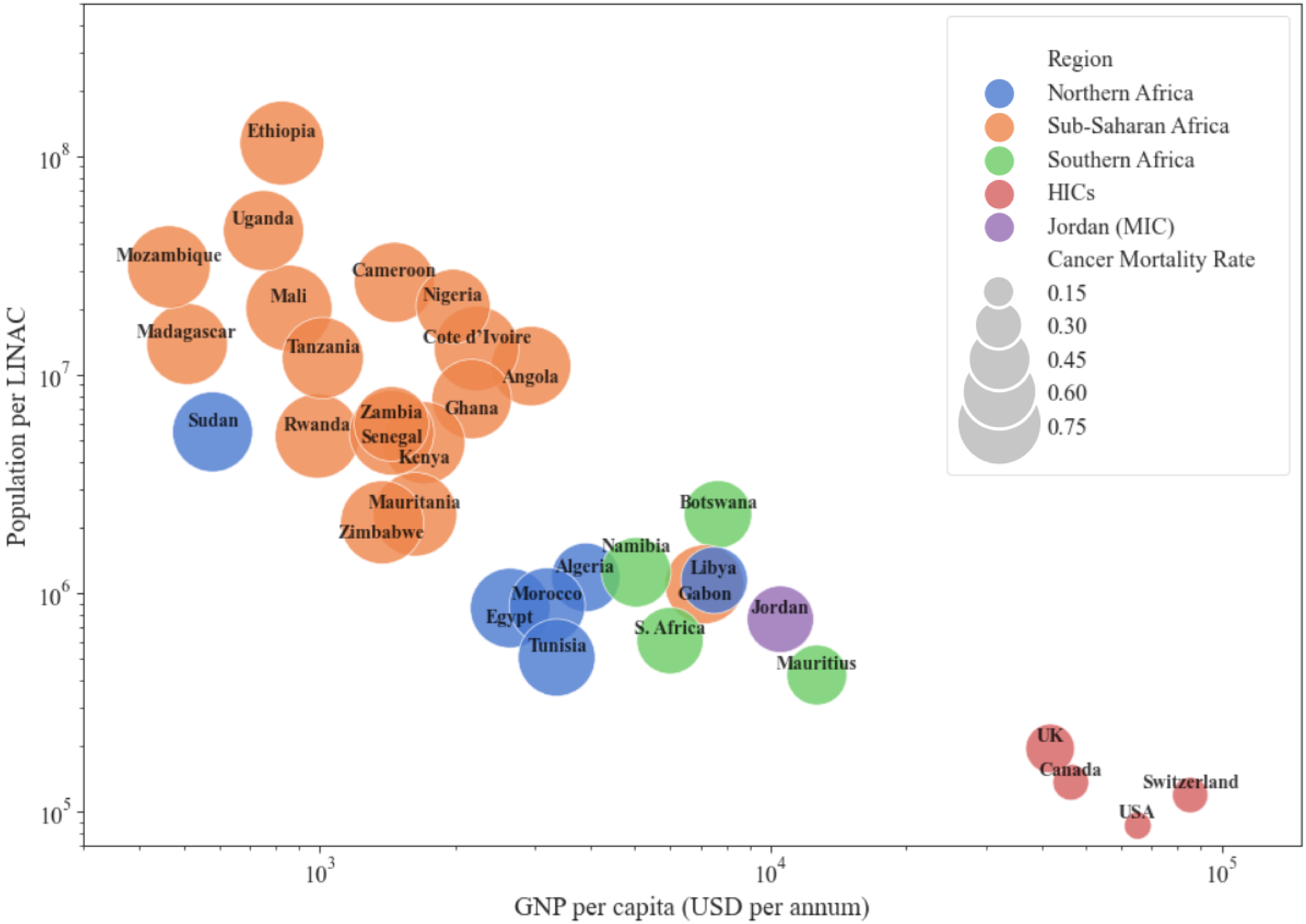
Capacity for Multi-disciplinary teams

- Clinical skill gaps
- Need for training programs following global trends
- Lost time and high cost of short training time abroad

RECOMMENDATIONS

- Regional (AU – African Union) and Sub-regional entities like ECOWAS should play a catalytic function in addressing the cancer conundrum in Africa by harnessing and deploying resources in the establishment of RT and other ancillary infrastructures. Should also facilitate cross-border and seamless access to treatment facilities in the countries within the region.
- National Cancer Control Programmes should be instituted in the Member States that have none as this is a veritable metrics to monitor the progress or lack of it in the Cancer minimization and eradication efforts.
- Bilateral and Multilateral partnerships should be explored to fully or partially fund the purchase of equipment and training of all cadres of staff like the IAEA’s counterpart funding scheme and the assistance of international NGO’s like ICEC etc.

GNP per Capita and the Ratio of Inhabitants to RT Machines and Cancer Mortality Rates



A rethink of the linear accelerator for resource-limited environments

Manjit Dosanjh

AAPM Session on Affordable Cancer Care for All

Current status

- The burden of cancer is increasing globally
- Large shortfall in LIC and LMIC RT systems that are needed for effective cancer care
- LINAC-based RT is the current technology of choice

But LINAC technology is **complex, labour intensive, and high cost** to acquire, install, operate and service.

Can we use technology developments to address the current challenges and make RT more widely available and expand access globally?

1st workshop on:
"Design Characteristics of a Novel Linear Accelerator for Challenging Environments"

Norman Coleman(ICEC) David Pistenmaa (ICEC) Manjit Dosanjh (CERN)

http://indico.cern.ch/event/560969/

European Organization for Nuclear Research (CERN)
International Atomic Energy Agency (IAEA)
James Martin Center for Nonproliferation Studies (CNS)
National Aeronautics and Space Administration (NASA)
National Nuclear Security Administration (NNSA)

Medical Linacs for challenging environments

- 1st Design Characteristics of a Novel Linear Accelerator for Challenging Environments, November 2016, CERN
- 2nd Bridging the Gap Workshop, October 2017, CERN
- 3rd Burying the Complexity Workshop, March 2018, Manchester

- 4th Accelerating the Future Workshop, March 2019, Gaborone

CERN

International Cancer Expert Corps
Partnering to transform global cancer care

UKRI Science and Technology Facilities Council

Project STELLA

Smart **T**echnologies to **E**xtend **L**ives with **L**inear **A**ccelerators

Project STELLA is a unique global collaboration involving some of the **best physics** and **medical talent, expertise from leading laboratories in accelerator design** and, importantly, **input and collaboration** from users in **Africa, other LMICs** and **HICs.** The goal of this project is to design disruptive technology for the treatment of cancer patients with radiation therapy.

Innovative Technologies towards building Affordable and Equitable Global Radiotherapy (ITAR)

- **Gather information** from African hospitals/facilities regarding challenges faced in providing radiotherapy in Africa
- **Identify** the challenges with those who live with them day-to-day
- **Create design specifications** for a radiotherapy machine to meet these challenges for an improved design
- Assess applications of **ML, AI and use of cloud-computing** in African and LMIC settings
- **Concept design report** for a prototype

STELLA questionnaire - data gathering

Overview

We asked a range of questions shown in the table to at least one facility in all African countries with RT access.

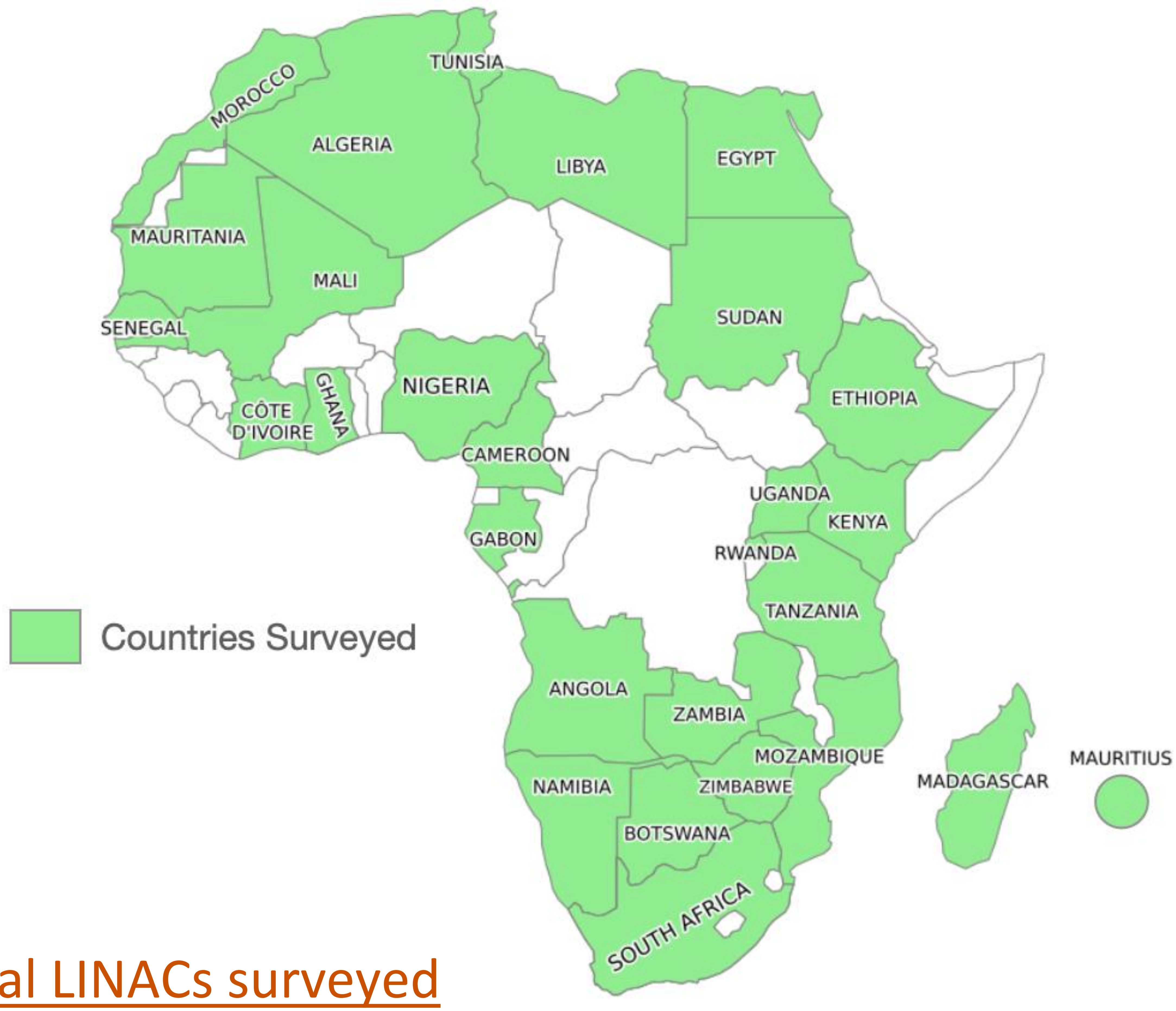
We examined: the LINAC model, environment, services, subsystems, treatment and imaging.

Also sent the survey to facilities in the UK, Canada and the USA, for comparison.

Focus	Questions
Model	What manufacturer and model? Year of installation?
	What number of treatments are performed per year on each machine?
Environment	What is the temperature and humidity in the area?
	What is the speed and availability of the internet connection?
	How reliable is the electricity supply?
	What is the floor area and ceiling height of the shielded area?
	What photon energy is your shielded area able to safely operate at?
Services	Do you have a service contract? Who provides it? What is the annual cost?
	How often does the machine have maintenance/tuning/calibration?
	What type of failures can you repair locally?
	Number of staff available for in-house repairs? Are staff formally trained?
Subsystems	How do you identify machine faults? Is it easy?
	Do you have problems with the vacuum system? How often?
	Do you have problems with the vacuum pump? Do you keep spares? Can you repair locally?
	Do you keep spare RF sources? Can you repair locally?
	Do you have problems with the MLC? Do you keep spares? Can you repair locally?
	Do you have problems with the electron gun? Do you keep spares? Can you repair locally?
	How much down-time do you experience?
	Do you have any software problems?
Treatment and Imaging	Does your hospital have diagnostic CT near the radiotherapy area?
	Do you use a tilting Couch? How important is this feature?
	How important is it for a LINAC to offer electron treatment mode?

Data African countries that have LINAC-based RTand from HICs

Country	Total number of LINACs surveyed
UK	25
USA	14
Canada	11
Switzerland	2
Jordan	1



Total LINACs surveyed

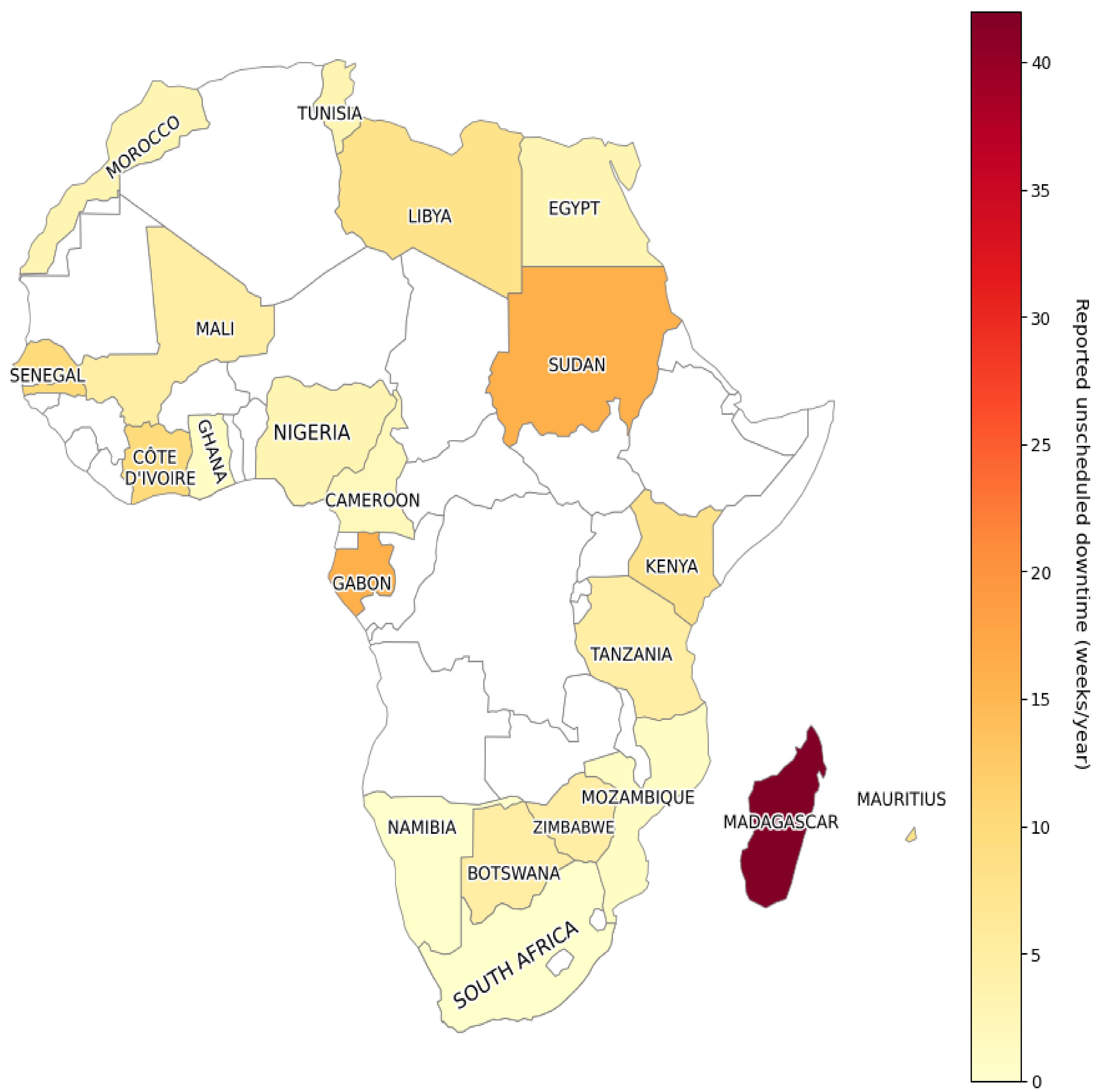
HICs: 52

Africa: 59

Map showing experienced downtime

What is actually responsible for this downtime?

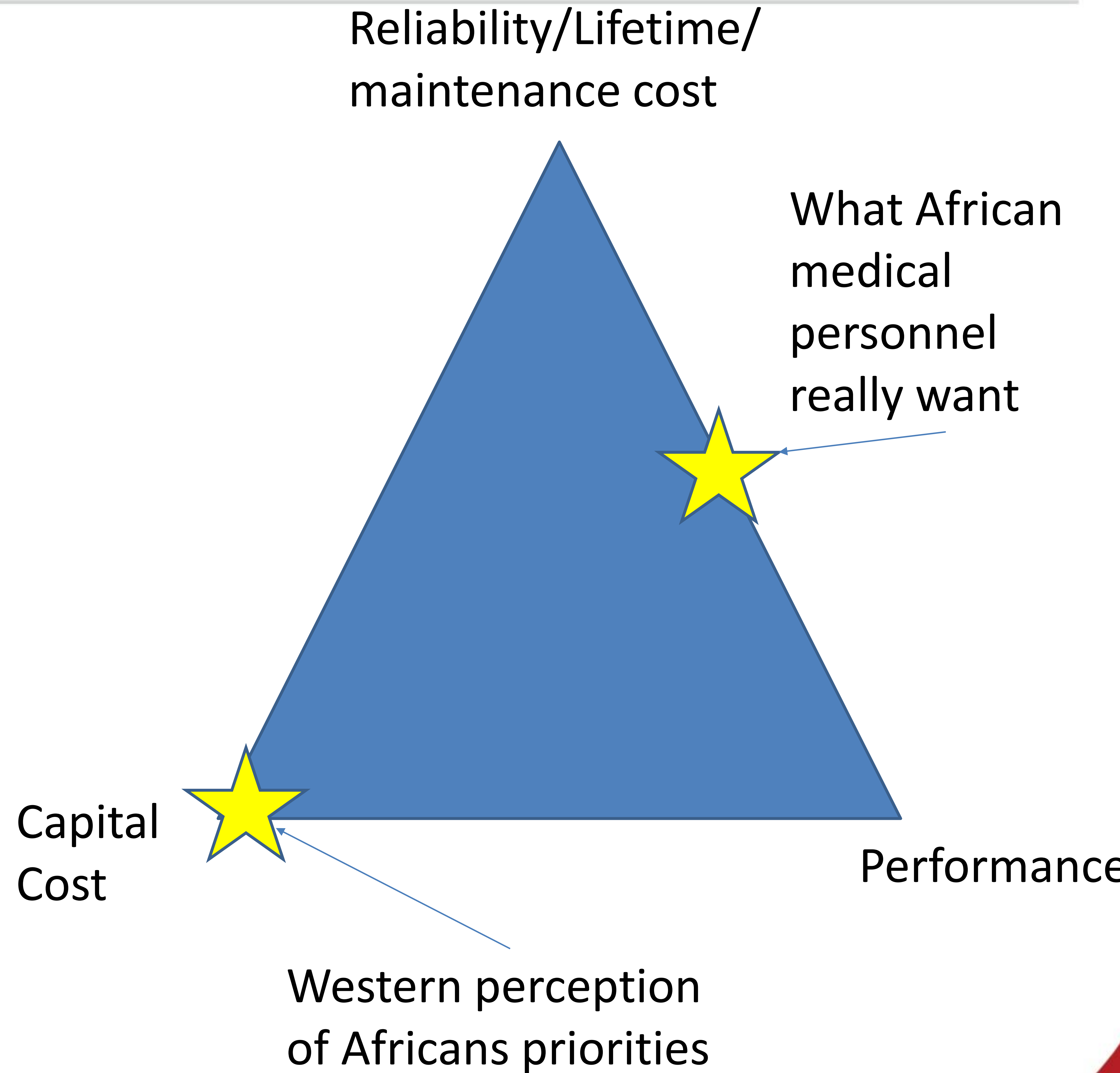
- We are investigating the impact of different responses on machine downtime.
- Univariate and multivariate analysis: observe how distributions of downtime vary for facilities grouped by question response.
- Also surveyed facilities in the UK, Canada, Switzerland and the USA, for comparison.



Biggest issues in LMIC hospitals

Graeme Burt

- Delays in repairs
- Lack of funds for regular maintenance
- Lack of trained engineers
- Fluctuating electrical supply
- Corruption



What isn't wanted

- Cheap, poorly made linacs and second-class treatments

Project Goals for RT-LINAC

- **Key issues** from reviewing **the various surveys, data gathering exercises, failure mode data and discussions at workshops**
- Categorisation Priorities:

Machine	• Severities and cost of repairing technical failures • Frequency of failures (i.e. component lifetime) • Easy upgradability • Size of the machine
Environment	• Making the electrical system robust to fluctuations and minimising the power requirements • Robustness to temperature fluctuations and dust • Initial capital cost and the cost of spare parts • Delivering higher dose
Staffing	• Staff training and skill requirements to run a RT machine • Ongoing education, mentoring and sharing experience

Summary of current findings

- Local repair and access to parts significant factor determining downtime
- Software problems are a major contribution to downtime
- Frequency and voltage fluctuations also appear important
- Current data suggests- component importance on downtime: **Electron Gun**, **Vacuum Pump, MLC, RF source, Software, Power Fluctuation**

Ultimate Goal

- Robust, modular, reliable and simple to use machines
- Are affordable
- with the aim to: expand access to RT

STELLA is looking at innovative design for reduction in acquisition and operating costs ensuring more improved LINAC access and a mentoring and training program for a sustainable solution

This work would not be possible without the great collaborators: ICEC, ITAR, STELLA, LMIC Colleagues https://www.iceccancer.org/