How do we translate design characteristics into a working machine

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with the collaboration of

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ICEC-2016, CERN, November 8, 2016

No conflict of interest

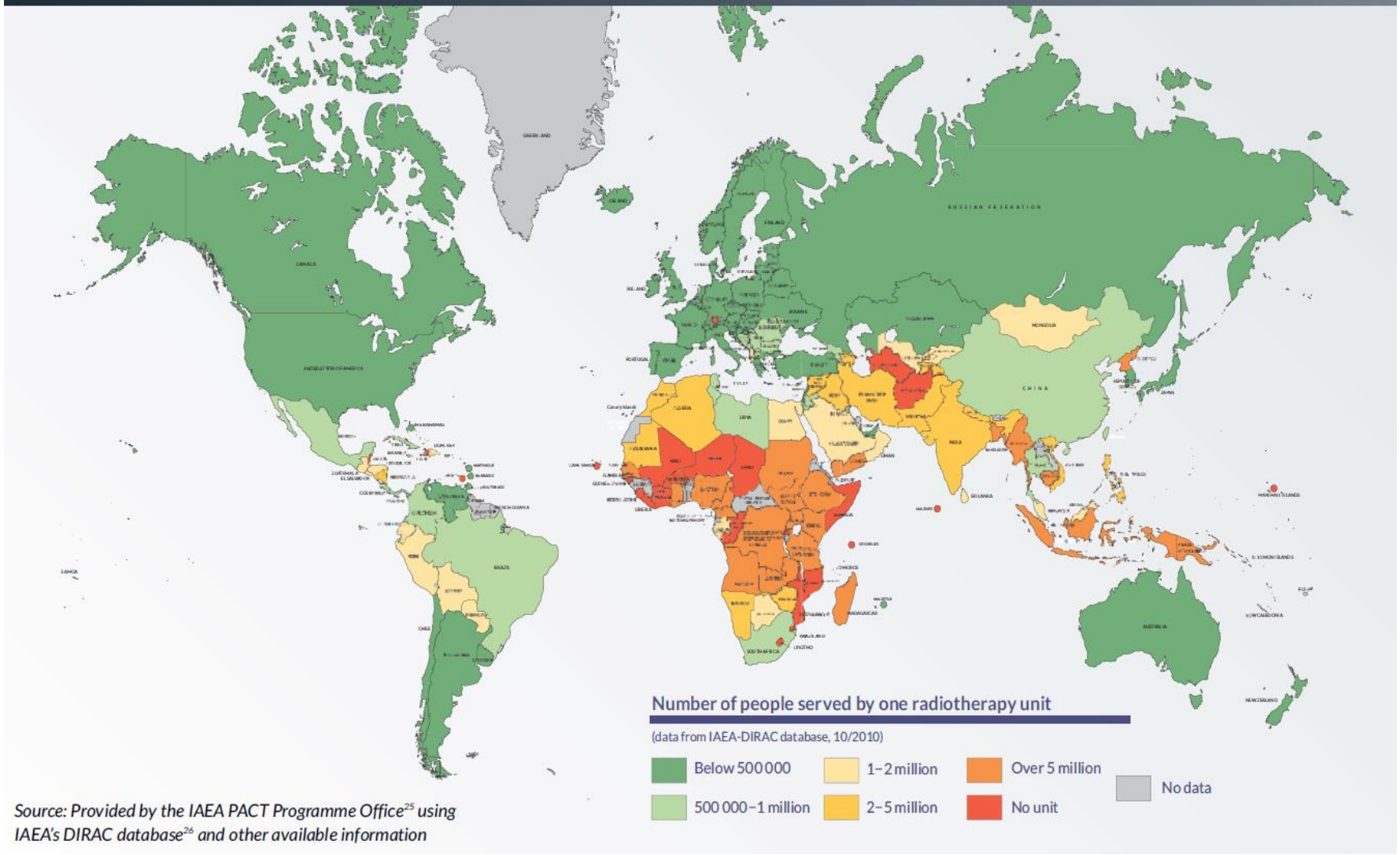
Analysis Outline

- Setting the scene
- Minimum requirements
- Radiotherapy equipment in low-income countries: tentative roadmap
- Main on-site boundaries
- Conclusive remarks

Table 1: Estimated trends in cancer incidence[a] (IARC, Globocan 2008)

	2010	2020	2030
More developed countries	5,719,728	6,583,577	7,425,611
Less developed countries	7,521,150	9,917,509	12,876,263

Figure 2: Global access to radiotherapy



Source: Provided by the IAEA PACT Programme Office[25] using IAEA's DIRAC database[26] and other available information

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Overview

Need for Radiotherapy in Low and Middle Income Countries – The Silent Crisis Continues

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Data and calculations relevant to external beam radiotherapy in low and middle income countries (LMIC)

LMIC		Total	LIC	L-MIC	U-MIC
Number of countries		124	35	44	45
Population (million)	A	5761.0	837.8	2525.2	2398.1
%		100%	14%	44%	42%
New cancer cases/year	B	7 964 367	675 500	2 358 267	4930 600
Number of radiotherapy courses/year	$C = B \times 0.5053 \times 1.25$*	5 030 353	439 981	1 482 826	3107 546
Number of radiotherapy fractions/year	$D = C \times 16.31$	81 991 583	7 202 258	24 153 656	50 707 313
% of countries without radiotherapy		31%	66%	27%	9%
Number of existing machines	E	4221	62	1014	3145
Number of LINAC	F	2919	25	523	2371
Number of Co^{60} machines	G	1302	37	491	774
% of Co^{60} machines	G/E	31%	60%	48%	25%
Machines/million population	E/A	0.733	0.074	0.402	1.311
Radiotherapy courses/machine (450/year − 8 h/day)	C/E	1192	7096	1462	988
Fractions/machine (9600/year − 10 h/day)	D/E	19 425	116 165	23 820	16 123
Total machines needed (1 x 450 courses/year −8 operating hours/day)	$H = C/450$	11 179	978	3295	6906
Additional machines needed	$I = H-E$	6958	916	2281	3761
% of needs currently covered	E/H	38%	6%	31%	46%
Total machines needed (1 x 9600 fractions/year −10 operating hours/day)	$J = D/9600$	8541	750	2516	5282
Additional machines needed	$K = J-E$	4320	688	1502	2137
% of needs currently covered	E/J	49%	8%	40%	60%

LIC, low income countries; L-MIC, lower-middle income countries; U-MIC, upper-middle income countries.

* This radiotherapy utilisation rate was obtained retrospectively by dividing the addition of radiotherapy courses for each country by the number of cancer cases.

Data and calculations relevant to external beam radiotherapy in Africa

Africa		Total	LIC	L-MIC	U-MIC
Number of countries		51	26	16	9
Population (million)	A	1069.5	510.4	427.3	131.9
%		100%	48%	40%	12%
New cancer cases/year	B	843 900	360 600	332 900	150 400
Number of radiotherapy courses/year	$C = B \times 0.543 \times 1.25$	572 755	244 739	225 939	102 076
Number of radiotherapy fractions/year	$D = C \times 16.44$	9 415 182	4023 125	3 714 083	1677 975
% of countries without radiotherapy		55%	81%	44%	0%
Number of existing machines	E	278	15	136	127
Number of LINAC	F	194	7	97	90
Number of Co^{60} machines	G	84	8	39	37
% of Co^{60} machines	G/E	30%	53%	29%	29%
Machines/million population	E/A	0.260	0.029	0.318	0.963
Radiotherapy courses/machine (450/year − 8 h/day)	C/E	2060	16,316	1661	804
Fractions/machine (9600/year − 10 h/day)	D/E	33 868	268 208	27 309	13 212
Total machines needed (1 x 450 courses/year −8 operating hours/day)	$H = C/450$	1273	544	502	227
Additional machines needed	$I = H - E$	995	529	366	100
% of needs currently covered	E/H	22%	3%	27%	56%
Total machines needed (1 x 9600 fractions/year −10 operating hours/day)	$J = D/9600$	981	419	387	175
Additional machines needed	$K = J - E$	703	404	251	48
% of needs currently covered	E/J	28%	4%	35%	73%

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Feature Comparison

Key Features	Accuray CyberKnife M6	Brainlab Vero	Elekta Versa HD	Varian TrueBeam
Photon Energies, MV	6	6	6 to 18	4 to 25
Max Dose Rate, MU/min	1,000	500	2,200	2,400
MLC Leaves	41	60	160	120
Max Field Size, cm	10 x 12	15 x 15	40 x 40	40 x 40 or 22 x 40
Leaf Size, mm (width at isocenter)	2.5	5	5	2.5-5 or 5-10
Cone Beam CT Imaging	No (ceiling-mounted stereo x-ray)	Yes	Yes	Yes
Respiratory Gating	Synchrony	ExacTrac Gating	ABC	RPM
6D Treatment Couch	RoboCouch	No (5D table + 1D o-ring)	HexaPod	PerfectPitch
Volumetric Arc Therapy	Not applicable	Dynamic Wave Arc	VMAT	RapidArc
SBRT	Yes	Yes	Yes	Yes

"We've found a mass. The good news is we have weapons of mass destruction."

From ECRI Institute, 2015

Some clues to facilitate on site access to treatment accuracy

- Commissioning :
  - Finalize training before commissioning
  - develop a simple water-tank free commissioning process
  - provide all the necessary equipment with the machine

- Provide reference beam data and a TPS already configured (on a local PC, but possibly also online e.g. via remote connection)

- Allow self-diagnosis by the machine of technical problems, and internal checks of beam output

Checklist for Linear Accelerator

- **Ease of Use**
  - Implement straight forward setup procedures and automated workflows to improve efficiency.
- **Reliability**
  - Get commitments to keep high uptimes.
- **Siting Requirements**
  - Spec out minimum room size, and required shielding.
- **Implementation**
  - Head for dedicated project management to ensure a smooth installation process.
- **Service and Support**
  - Negotiate for long-term service commitments.
- **Training**
  - Set out clinical applications training to realize full benefits.
- **Cost**
  - Optimize capital cost, annual service fee, and quality assurance tools.

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Desirable features regarding LINACs designed for LICs (I)

adapted from Pomper MA et al. The Stanley Foundation, CNS, February 2016

- To be able to function despite:
  - regular interruptions to the power supply,
  - lack of air temperature control in buildings.
- Environmentally friendly radiotherapy accelerator that:
  - consumes little power on standby , and has low instantaneous power demand,
  - has reduced heat production.
- Other desirable features of such LINACs:
  - to be highly modular, so that parts can be easily exchanged,
  - to be self-diagnosing if the machine becomes non-functional.

Desirable features regarding LINACs designed for LICs (II)

(adapted from Pomper MA et al. The Stanley Foundation, CNS, February 2016)

- A developing-world LINAC with modular enhancements, as capability increases: an option for LINAC companies to consider.

- Costs could be phased in by starting with a basic unit, and options could be provided for:
  - new technology,
  - remote diagnosis and adjustment,
  - a long-term maintenance contract with the vendor.

Language: use, interfaces and training

Language of instruction for use:

- The instruction for use for a medical device needs to be written in the local language by the manufacturer.

Human-machine interface language:

- Where a device bears instructions required for its operation by means of a visual system, such information must be understandable to the user.

Training language:

- Some training courses are only taught in English. As a minimum, to guarantee the assistance of a translator in order to facilitate interactions.

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How to make it happen?
Some potential hurdles…

- Frequent power cut, or unstable power line.
- Dusty atmosphere and/or moisture in the atmosphere (tropical countries), which means condensation, rust and humidity problems.
- Unstable water pressure. Dirty running water: water treatment facility might be necessary.
- The heat might be an issue, when it is 45°C outside, with a not so reliable air conditioning system.
- Parts stuck 3 or 4 weeks at the custom is not abnormal.
- Initial budget is provided to buy the equipment, but there is no budget for maintenance down the line.

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Some conclusive remarks (I)

Developing countries: from problems to opportunities

- Bottom line: in developing countries, access to radiotherapy is blocked by both high treatment equipment costs and infrastructure requirements that developing countries can't afford.

- Does this mean that we should reduce these costs by limiting machine functional capacities?

  - It's deeply unfair to restrict the access to standard quality treatment solely because of the inability of developing countries to invest in costly equipment.

Some conclusive remarks (II)

Developing countries: from problems to opportunities

- So what? Indian labs have been authorized to market Sovaldi (hepatitis C) in 91 countries at a price of 900$ (in USA and Europe: 84'000$).
  - Interactions between foundations to provide «all inclusive» models of delivery and maintenance.

- Telematics including on-line training procedures in order to
  - reduce on-site human resources needs,
  - promote higher quality treatments.

German Radiotherapy Clinic Harnesses Sun to Run Systems, Cuts Dependence on Power Grid

Lake Constance
Radiation Oncology Ctr
Singen, Germany

In August 2011, the Centre installed an array of 232 solar panel modules on its roof, creating a 400m2 energy collector that converts sunlight into hundreds of kilowatt-hours of electricity daily.

During the summer, the array's output runs its two Elekta Synergy® systems, a large bore CT system and the clinic's IT technology, lighting and air-conditioning.

Let's not forget ….:
The quadrature of the circle

To know the road ahead,
ask those returning …

Ancient Chinese proverb recorded by
Confucius, more than 3'000 years ago


Thank you