The use of simulation modelling to improve the radiation therapy planning process

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Introduction

• Team
  • Collaboration between BCCA and CHCM/Sauder School of Business UBC
  • BCCA: Dr. Scott Tyldesley, John French, Dr. Thomas Pickles, Dr. Thomas Keane
  • UBC: Dr. Martin Puterman, Dr. Steven Shechter, Mariel Lavierí, Greg Werker, Antoine Sauré

• Successful Grants
  • Canadian Institute for Health Research (CIHR) (1.5million over 5 years)
  • Michael Smith Foundation for Health Research (35,000 team planning grant)

• Overall goal
  • To develop, test, and implement modern management practices, especially from the field of Operations Research (OR), to increase the efficiency of the cancer system and to enhance patient outcomes
  • Build a simulation model of a provincial radiation therapy program

• Intent of this project
  • demonstrate that a simulation model is appropriate
  • develop first phase of larger simulation project
Why this study?

- This model is the beginning of a larger effort to model the entire provincial RT program, at macro and micro levels, to better understand the system and to suggest improvements and identify scenarios for improvement.

- RT treatment planning at Vancouver Centre:
  - currently 4-10 days (5.85 days average)
  - believe it could be shortened to an average of 3-4 days
RT Planning Process

CT Scan, SV transfer → RO Input → RO Verified

- YES → Phys. Consult
- NO → CT Scan, SV transfer

Phys. Consult

- YES → Dose Generation
- NO → Phys. Consult

Dose Generation

- YES → Std. Plan
- NO → Phys. Consult

Std. Plan

- YES → Plan Completed
- NO → Plan Inspection

Plan Inspection

- YES → Plan Approved
- NO → Plan Inspection

Plan Approved

- YES → Package Inspection
- NO → Plan Approved

Package Inspection

- YES → Package Approved
- NO → Plan Inspection

Package Approved

- YES → Plan Completed
- NO → Plan Inspection

Dose Completion or Review

- YES → Dose Approved
- NO → Dose Completion or Review

Dose Approved

- YES → Plan Inspection
- NO → Dose Approved

Plan Completed
Why Simulation?

• Complex system
  • process flow has different branches and loops
  • 16 cancer categories
  • 23 techniques

• Several resources – radiation therapists, radiation oncologists, medical physicists
  • many tasks
  • special skills within each resource type

• No way to determine a realistic analytical solution.
• Easy to test many “what-if” scenarios with the model.
What is Simulation?
(discrete event simulation)

- A methodological approach that uses...
  - a model of some system
  - (that includes many assumptions)
  - and the ability to generate random numbers (e.g., patient arrivals, processing times, decisions at process forks, …)
  - to imitate one possible system outcome.

- Then,
  - it runs over and over again to generate many possible outcomes
  - and estimates “average” outcomes.
Model Inputs

Arrivals

Resource Availability

Task Times

Historical data
Poisson process

Arrival Process

Percent Arrivals by Category

Historical data
Poisson process

12% 30-60 min
67% 1-2 hours
21% 2-4 hours

BC Cancer Agency
CARE + RESEARCH
An agency of the Provincial Health Services Authority

UBC Centre for
Health Care Management
THE UNIVERSITY OF BRITISH COLUMBIA

SAUDE
School of Business
Arrivals – Overall

Arrival Process

- Historical data
- Poisson process

Frequency vs. Arrivals per day (0-20)
Arrivals – Cancer Categories

Percent Arrivals by Category

Breast: 4 Field
Breast: 6 Field
Breast: Ant/Post Supraclav
Breast: Conformal/ Partial Breast
Breast: Electrons
Breast: MLC Comp
Breast: POP
Breast: Single Field
Breast: Tangents

Prostate & Testicular
Miscellaneous
Lymphoma
Lung
Head & Neck
Gastro-Intestinal
Esophagus
CNS
Cervix & Uterus
Brain
Bladder
Rectum

Breast (shown by technique as example of further details)
Resource Availability

- Therapists
  - 4 resources;
  - different skills
- Physicists
  - 2 resources
- Oncologists
  - more complex:

![Graph showing resource availability over time with blue bars indicating capacity.](image)
Task Times

• Main tasks:
  • Recent Survey Results, e.g.,

12%  30-60 min
67%  1-2 hours
21%  2-4 hours

• Gaps in data:
  • Interviews with planners and staff
• Why not use detailed historical data?
  • Includes queuing time
Validation

Actual Data vs. Simulation Results (by Category)

- Bladder
- Brain
- Breast
- Cervix & Uterus
- Esoph.
- GI
- H&N
- Lung
- Lymph.
- Misc.
- Prostate
- Rectum

Avg days in planning process

% difference
Simulation
Actual

0% 20% 40% 60% 80% 100%
Sensitivity Analysis - Scenarios

• All standard plans.
• Double “plan time” processing time.
• Arrivals increase 20%.
• Arrivals decrease 20%.
• Oncologist productivity at 80%.
• Oncologist productivity at 120%.
Sensitivity Analysis - Results

The diagram shows the planning time in days for different scenarios.

- **Base case**: Planning time ranges from 5 to 10 days.
- **All standard plans**: Planning time ranges from 5 to 10 days.
- **Double RT task time**: Planning time ranges from 5 to 10 days.
- **arrivals ↑ 20%**: Planning time ranges from 5 to 10 days.
- **arrivals ↓ 20%**: Planning time ranges from 5 to 10 days.
- **80% oncologist productivity**: Planning time ranges from 5 to 10 days.
- **120% oncologist productivity**: Planning time ranges from 5 to 10 days.

The best and worst cases are indicated:
- **Worst case** planning time:
  - Worst: 67 days
  - Avg: 43 days
  - Best: 25 days

The 95% confidence interval (C.I.) is also shown for each scenario.
What-if Scenarios

- One fewer RT
- One more RT
- Higher RT skills
- One fewer physicist
- More oncologist availability
- Consistent oncologist delays
- More “standard plans”
What-if Results

What-if Comparisons

Planning time (days)

Scenarios

- Base case
- One fewer RT
- One more RT
- Higher RT skills
- One fewer physicist
- More oncologist availability
- Consistent oncologist delays
- More standard plans

95% C.I.

Best case

Worst case
Conclusions

- Able to model RT planning at Vancouver Centre with simulation
  - great accuracy at a high level and good accuracy for most categories
  - suggests larger process can be modelled with simulation
- Resource levels
  - # Radiation Therapists is just sufficient
  - # Physicists is sufficient
  - # Oncologists is just sufficient
- The system could handle an increase in arrivals, with delays in processing time; a large decrease in arrivals does not considerably improve performance.
- Variability in oncologist steps, not actual processing time or oncologist availability, appears to have the largest effect on outcome