EXTREMITY DOSE ESTIMATES IN HDR STUCK SOURCE EMERGENCIES WITH UNKNOWN SOURCE POSITIONS

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PURPOSE

- To parameterize dose estimates to the extremity of a physician responding to an HDR stuck source emergency in which the exact spatial relationship between the source and the extremity is unknown

INTRODUCTION

- High dose-rate brachytherapy is used routinely worldwide without mishap
- This effective treatment modality is safe but it has the potential for unplanned, high exposure situations for patients and staff during emergencies (i.e. “stuck” source)
- The Canadian Nuclear Safety Commission requires licensees with brachytherapy remote afterloaders to carry out annual emergency training to help mitigate that risk
- Emergency training content varies from institution to institution, but typically involves simplistic scenarios with no patient surrogate and uncomplicated applicators
- Explicit source location during an emergency is unknown, creating the possibility for high doses – particularly for extremities

METHOD AND MATERIALS

- A previously designed HDR emergency response simulator was used to model the effect of source proximity
- The simulator consisted of a motion capture system that recorded comprehensive spatial information, with optically tracked reflective markers, representing the source and anatomical regions of the participants during the original trials

Motion Capture Technology

- Motion capture technology has valuable applications for wide-ranging fields, from filmmaking and animation to ergonomics, sport research and physical rehabilitation

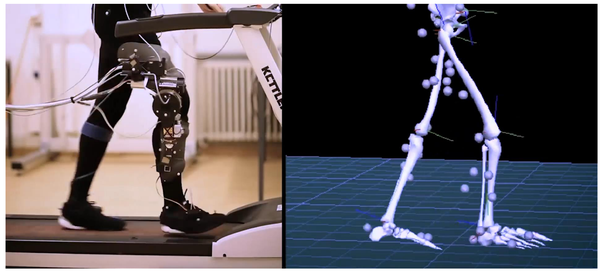


Figure 1: The experimental setup for research on external forces and gait. Note the optical markers in the left picture and their digital rendering on the right image. https://optitrack.com/applications/movement-sciences/

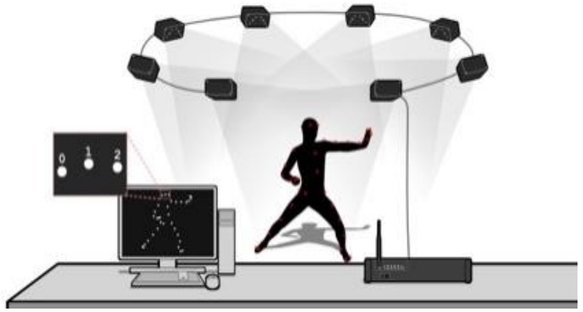


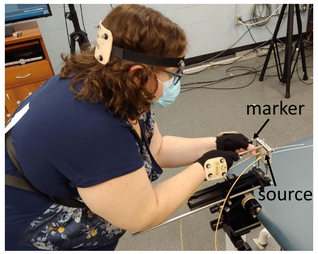
Figure 2: General setup of marker-based optical cameras for motion capture studies.

RESULTS

- For the shortest hand-source distance (3 mm), extremity dose reached 3.3 Gy for the most experienced emergency responder (0.016 Gy in the original trial)
- For the novice responder (who took 5X as long to put the source in the safe), up to 89 Gy was delivered with the 3 mm distance (0.108 Gy, originally)
- At 100 mm, the doses drop to 0.013 and 0.108 Gy, respectively

Parameterization

- Doses to markers representing the right and left fingers is the focus of this study
- 12 infrared cameras used to track 3D positions of each marker, with measurements acquired every 50 ms



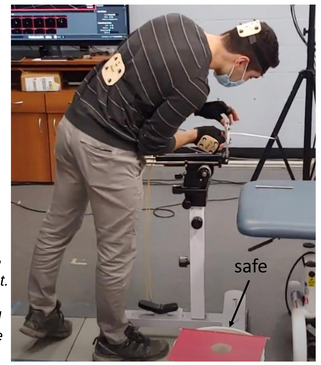


Figure 3: Participants simulating the response to a stuck source during a simulated treatment. The prostate treatment setup was the subject of this analysis, with the left finger marker and source labelled in the left picture, and the safe labelled in the right picture.

- Raw data was analyzed to pinpoint the time when the finger readings were closest to the source for each participant
- At that timepoint, the subsequent positions were then assigned a minimal distance ranging from 3 mm to 100 mm for the duration of the data points, representing the time until the source is deposited into the emergency safe
- The resulting doses to the hands were calculated and compared to our previously reported data

Participant	Doses (Gy)		
	3 mm	100 mm	Original
1	3.3	0.013	0.016
2	7.4	0.009	0.006
3	14.2	0.068	0.093
4	88.9	0.108	0.108

Table 1: Maximum doses for the extremities for the shortest and the longest distance in this study. Note that the original dose, strictly using the data acquired from the trials, is on the same order of magnitude as the 100 mm dose. Participant 1 is the most experienced responder, while participant 4 is the least.

- For all participants, the 100 mm trial was on the same order of magnitude to the dose in the original

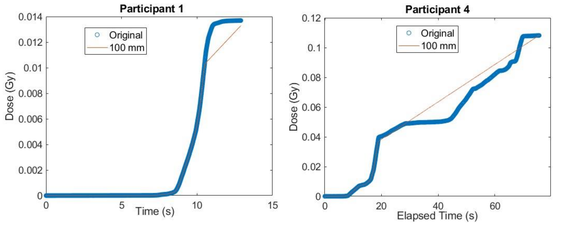


Figure 4: Cumulative doses for Part. 1 (experienced responder) and Part. 4 (novice responder), for their original runs (blue) and 100 mm distance runs (red).

- As in the original trials, a second try for an inexperienced responder showed a reduction in time and dose
- Participant 3 repeated the run immediately and achieved a max dose of 4.2 Gy (14.2 Gy originally)

CONCLUSIONS

- High doses to extremities are possible during a stuck source scenario, particularly if the source is within a few millimeters
- If the exact location of the source is unknown, doses can be reduced by limiting the period of exposure – which can be achieved through the routine practice of emergency procedures

ACKNOWLEDGEMENTS

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