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ONCOLOGY: BRIEF REPORT

# A model for in situ plan of care for a critically unstable pediatric patient following I-131 MIBG infusion

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## Abstract

Recent clinical trials have moved iodine-131 (I-131) metaiodobenzylguanidine (MIBG) therapy into frontline management of high-risk neuroblastoma. With this expansion, it is reasonable to anticipate the need for intensive care level resuscitations. Radiation exposure remains the greatest risk to health care professionals managing these patients. We combined shock simulation scenario data with actual radiation dosimetry data to create a care model allowing for aggressive, prolonged in situ resuscitation of a critically ill pediatric patient after I-131 MIBG administration. This model will maintain a critical care provider's radiation level below 10% of the annual occupational dose limit (5 mSv, 500 mrem) per patient managed.

## 1 | INTRODUCTION

Radioactive metaiodobenzylguanidine (MIBG) therapy is a targeted radiotherapy agent historically used for the treatment of relapsed or refractory neuroblastoma. Based upon promising response rates, recent clinical trials are moving MIBG therapy into front-line management of high-risk neuroblastoma.[1-8] Radiation exposure from iodine-131 (I-131) remains the greatest risk to health care professionals managing these patients.[9-11] In the United States, occupational radiation dose limits are found in Title 10, Part 20 of the Code of Federal Regulations (10 CFR 20), or in equivalent Agreement State regulations. The annual adult occupational dose limits are 50 millisievert (mSv) (5000 millirem [mrem]), and 5 mSv (500 mrem) for the embryo/fetus of a declared pregnant woman (during the entire pregnancy).[11,12]

Due to federal guidelines governing the release of individuals containing radioactive material (10 CFR 35.75),[13] patients receiving I-131 MIBG treatment are typically hospitalized in a shielded isolation room for 3-5 days, pending clearance of the I-131. In the event of acute, critical decline, it is undesirable for these patients to travel to diagnostic imaging or surgical suite facilities, or to have radioactive diagnostic samples sent to a clinical laboratory. During the infusion and in the days that follow, trained pediatric intensive care unit (PICU) and oncology team members are on-call to respond to emergencies including, but not limited to, sedation complications,

**Abbreviations:** mCi, millicurie; MIBG, metaiodobenzylguanidine; mrem, millirem; mSv, millisievert; PICU, pediatric intensive care unit; RT, respiratory therapist

anaphylaxis, septic shock, acute respiratory failure, cardiovascular instability (hypertensive crises, arrhythmias), and acute neurologic deterioration.

Radiation exposure to health care professionals for routine care of patients receiving I-131 MIBG treatment are historically very low (<0.45 mSv = 45 mrem per treatment).[14-16] Unfortunately, these data do not reflect a potentially protracted time period at the bedside that would be required to adequately resuscitate a pediatric patient after severe, acute deterioration. Because multiple MIBG therapy patients are managed at Michigan Medicine annually, as part of our clinical practice guideline, we have established a radiation exposure goal of 5 mSv (500 mrem), or 10% of the annual occupational dose limit per health care professional per patient managed. Our goal was to create a care model that would allow for aggressive, in situ resuscitation of a critically ill pediatric patient after I-131 MIBG administration, while controlling occupational radiation doses for all care providers within our radiation exposure limit.

## 2 | METHODS

A failure mode effects analysis identified staffing needs as our greatest barrier in resuscitating a patient with acute, severe shock immediately after MIBG infusion in the original acute care location. Therefore, we coupled dosimetry data from a pediatric patient during and after MIBG infusion with data from a shock resuscitation simulation to generate a proposed staffing model.

### 2.1 | Case study

Concurrent with an existing MIBG treatment protocol approved by the institutional review board, we placed five radiation dosimeters (Landauer OSL) in selected locations of the isolation room (Figure 1). An 11-year-old female with high-risk neuroblastoma received 811 millicurie (mCi) (15.1 mCi/kg) of I-131 MIBG. Dosimeters recorded exposure over selected time intervals for the first 96 h after the infusion started.

### 2.2 | Shock scenario simulation

We also completed a paper simulation of a patient experiencing an acute shock-type event after the start of MIBG infusion and requiring 4 days of intensive care management in situ. The scenario chosen was cardiac arrest, requiring full resuscitative efforts, including placement of monitors, rapid sequence intubation, mechanical ventilation and suctioning, peripheral, central venous, and arterial vascular access completed in series, initiation and titration of vasoactive infusions, administration of sedation, analgesia, antibiotics, and other medications, and emergent diagnostic testing. Emergent diagnostic testing for the deteriorated MIBG patient was limited to point-of-care blood testing and chest and abdominal radiographs.

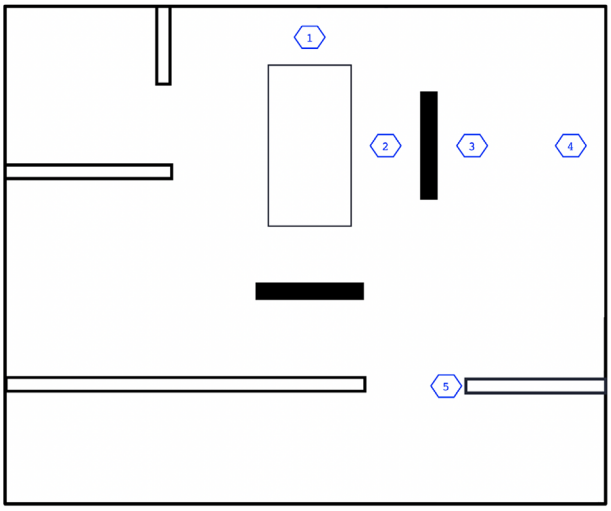


**FIGURE 1** Schematic of actual patient room noting each of the five radiation dosimeter locations. Dark lines represent portable lead shields. Double lines represent walls. Rectangle represents patient bed. Hexagons represent locations of dosimeters: 1, at the head of bed; 2, at the side of bed but in front of lead shield; 3, at the side of bed but behind lead shield; 4, on wall within room; 5, at doorway entrance to metaiodobenzylguanidine (MIBG) room

The shock simulation scenario data were merged with dosimetry data to estimate radiation doses for each team member, accrued across all time phases for the first 4 days after MIBG administration. The scenario accounts for the dynamic movement of each team member among five different positions in the isolation room (Table 1, Figure 1) and radiation dose rate reduction from the physical decay[15] of I-131 and biological clearance of MIBG. Assuming team members work 8- or 12-h shifts, we determined the staffing model required to effect this same care in a real-life situation (Table S1).

## 3 | RESULTS

The highest dose rate is in position 2, at bedside and in front of the lead shield. Estimates indicate that a team member can remain in position 2 for the first 5 h after infusion, the time of greatest radiation exposure, before reaching 5 mSv (500 mrem). The next highest dose rate is in position 1 (head of the bed), although the dose rate was often less than 25% of the dose rate in position 2. Any position behind a lead shield results in substantially less exposure (Table 1, Figure 1).

The simulation resulted in time-spent estimates of 288 min for PICU nurse, 155 min for PICU physician, 146 min for oncology nurse, 58 min for oncology physician, and 76 min for PICU respiratory therapist (RT).

Taken together, these data determined our staffing model (Table S1):

a. *PICU physician*: Two pediatric intensivists will be necessary, each prepared to work 12-h shifts for the first 96 h after the start of

**TABLE 1** Mean radiation doses

| Time period dose rate (mrem/h) | 0-4 h | 4-16 h[a] | 16-24 h | 24-48 h | 48-75 h | 75-96 h |
|---|---|---|---|---|---|---|
| 1 - Head of bed | 56 | 23 | 27 | 15 | 14 | 3 |
| 2 - Side of bed - in front of shield | 103 | 89 | 96 | 59 | 34 | 21 |
| 3 - Side of bed - behind shield | 5 | 2 | 1 | <1 | <1 | <1 |
| 4 - Side wall of patient room | 18 | 3 | 1 | 3 | 2 | 2 |
| 5 - Doorway to patient room | 5 | <1 | <1 | <1 | <1 | <1 |

*Note*. Radiation doses (mrem/h; 1 mSv = 100 mrem) recorded over selected time intervals for the first 96 h after iodine-131 (I-131) metaiodobenzylguanidine (MIBG) infusion start at each of the five patient room locations.
[a] Exact time frame for this interval was 4-16.6 h.

MIBG infusion. A third intensivist should be available in the event that one of the two primary intensivists needs assistance.

b. *PICU nurse*: For the first 24 h, six PICU nurses will be needed, each working 8-h shifts and rotating in 4-h intervals between positions 2 and 3. After the first 24 h, PICU nurses may work a 12-h shift in all the positions.
c. *Respiratory therapist*: For all time periods, one RT will be needed and may work 12-h shifts.

## 4 | DISCUSSION

While maximal medical and surgical intensive care may not be an option for patients receiving MIBG therapy due to radiation safety concerns, this case study describes how critical care therapies may be safely applied in situ for the first 4 days after the start of the infusion. Our data indicate that a team member spending all the time at the location of highest radiation dose rate (at bedside and in front of the shield) would not exceed 10% of the annual occupational dose limit, unless remaining in that position for more than 5 h. The goal of 5 mSv (500 mrem) per patient allows team members to safely manage multiple patients annually, even in the unlikely event of multiple deteriorations.

As these data reflect one patient and one simulation, our proposed model recommends use of real-time dosimeters for quick, on-demand monitoring, worn by each team member, with accumulated doses assessed after the first 4 h and at 24-h intervals to assist in refining the need for staffing rotation. When possible, we recommend only one physician, nurse, and RT be in the room, and team members should stand near the door or behind a lead shield. Finally, should any team member exceed 5 mSv (500 mrem), we recommend they rotate out of the isolation room into the anteroom (position 5) for all remaining time.

As MIBG treatment trials expand enrollment to include younger children and infants, as well as intravenous or multidrug sedatives to ensure patient tolerance of the treatment, it is reasonable to anticipate the need for intensive care level resuscitations.[17] Our model endorses that pediatric critical care level resuscitation and management can be achieved in situ while adequately controlling occupational radiation exposures.

Ongoing work is necessary to replicate our findings, perhaps with shorter monitoring periods, use of instantaneous monitoring, and in patients receiving different doses of I-131 MIBG.

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## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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