MR Compatible Incubator for Imaging Pre- and Term Neonates

R. Srinivasan[*], T. Loenneker-Lammers[^] and R. Shah[†]
[*]Advanced Imaging Research, Cleveland, OH [^] Lammers Medical Technology, GmbH, [†]Department of Radiology,
Case Western Reserve University, Cleveland, OH

Abstract Submitted
to
ISMRM 10th Scientific Meeting, Honolulu, Hawaii, May 18-24, 2002

ABSTRACT MR is a versatile tool best suited for imaging the premature neonate brain [1]. Despite its usefulness, its utility is extremely limited for imaging sick patients in the neonatal intensive care unit (NICU), because of the challenges we face in the life support of the infant during transport and during MR examination. The goal of this research is a) to build and evaluate a MR compatible incubator (MRCI) that will allow safe movement of the infant between the NICUs and MRI sections and b) to integrate high signal-to-noise (S/N) radio-frequency (RF) head coils capable of routine clinical MR examinations of ill newborns.

METHODS The MRCI of Figure 1 was built and evaluated on 1.5T and 0.23T MRIs at MetroHealth Medical Center (MHMC), OH. Performance of the MRCI was evaluated outside the scan room and inside the magnet. MR measurements were made with the MRCI ON and OFF. In addition, an end-capped birdcage coil [2] sufficient to cover 95^{th} percentile of the head sizes for the newborn population was built and compared to a commercial adult knee coil at 1.5T.

DESCRIPTION The MRCI was roughly 5' long and weighed 85lbs. It consisted of three sections; patient, aggregate and electronics which were located sequentially (see Figure 1). The patient section was 11" wide, 8" high and 32" long. It housed a patient bed and had space to place a RF coil through a flap located at the rear of the incubator. The aggregate section consisted of the air warming and humidity generating devices, sensors/safety devices, water reservoir, particle air filter inline with openings for air/oxygen intake. The electronics section consisted of control, feedback circuits, alarms, reset buttons and a user-friendly display sub-section, which had turn-dial push buttons for setting desired temperature and humidity levels. The LEDs displayed operator set and actual values inside the MRCI.

Temperature (25-39EC) and humidity (30-85%rH) levels set by the operator was attained by forcing the air in to the patient section (underneath and alongside the patient bed) and circulating it through the aggregate section and back while introducing fresh air through a particle filter located in the aggregate section. Air was warmed in the aggregate section using a heating element. Humidity was generated hygienically by boiling water through a second heater. O_2 enrichment (up to 75%) can be achieved by introducing oxygen to fresh air. Temperature, humidity and oxygen were regulated using feedback from sensors located in the patient and aggregate sections.

The MRCI was made of poly-carbonate and plastic composites that were MR compatible. Leads of the electronic circuits were chosen to be non-magnetic (tin, copper, strontium).EMI compatibility and RF isolation was maintained by using broadband and narrow-band filters. RF isolations of -55dB and -4dB were achieved using a narrow-band tuned RFC (L=1.5uH, C=3.3pF) at 1.5 and 0.23T. Electronic circuits were housed in several aluminum boxes which were connected to each other and grounded to the MRI magnet via a 110VAC wall outlet inside the MRI room. It was ensured this wall outlet was grounded to the MRI room shield.

RESULTS Temperature rise in the patient section from 25 to 38EC was achieved in roughly 30 minutes, see Figure 2. Please note, the temperature curve bounced back quickly despite a brief opening of the transparent double-walled hood over the patient section which demonstrated an efficient operation. The performance of the MRCI was identical outside and inside the MRI room.

Measurements with the MRCI ON and OFF exhibited a 3% loss in phantom S/N at 1.5T with no noticeable loss at 0.23T (Table 1). Uniformity was within 1%, ghosting and geometric distortions were within 0.1%. The NMR frequency reduced to <1ppm, but remained stable when the MRCI was ON. This may be due to the presence of a DC motor, which encompassed a small neodymium magnet (~5g).

Phantom comparisons to the commercial knee coil at the coil center resulted in a 21% S/N improvement (data not shown) in favor of the custom developed pediatric head coil. The end cap assisted in increasing the S/N while retaining the RF uniformity toward the solid end, with a rapid fall off of the B field toward the open end of the coil. This behavior will assist to minimize the signals aliasing from the upper chest in to the brain of newborns.

CONCLUSIONS A MR compatible incubator and a newborn head coil were successfully built and evaluated. Improvements to the MRCI will be made for efficient operation between 0.1 to 3T field strengths. Future plans are to incorporate skin temperature and SpO_2 measuring hardware within the MRCI, to integrate ECG, heart rate and blood pressure measuring equipments (to the MRCI), build them on to a MRI compatible trolley for patient transport between the NICU and the MRI section.

REFERENCES

1. Pediatric Neuroimaging, MRI Clinics of North America, February 2001 (and references therein).
2. CE Hayes, 5^{th} SMRM, Book of Abstracts, page 39-40, 1986.

ACKNOWLEDGEMENTS

This work was funded in part by grant R43NS38028 from the NIH.

Figure 1. MR Compatible Incubator (MRCI)

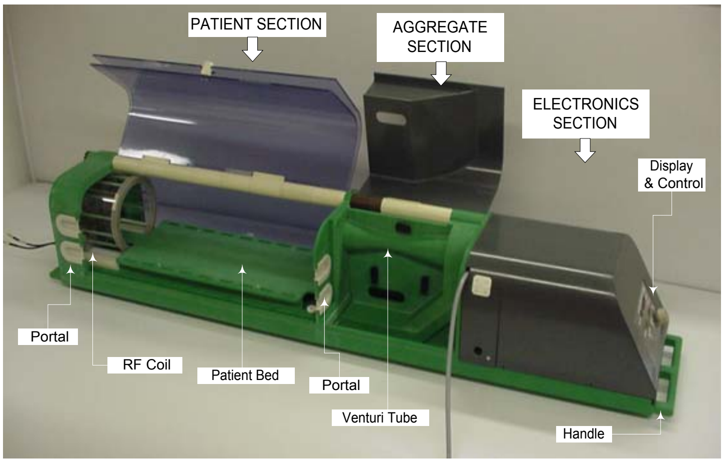

Table 1. MR measurements with the MRCI ON/OFF at 1.5 & 0.23T.

MRCI	S/N	Uniformity %	MR Freq MHz
OFF - 1.5T	182 ∀ 4	89 %	63.725081
ON - 1.5T	176 ∀ 4	90 %	63.725075
1.5T S/N Protocol: TR 800/TE 30, FOV 20cm, 128x256, 5mm slice, 1 acq,1:42min			
OFF - 0.23T	254 ∀ 8	90 %	9.800011
ON - 0.23T	261 ∀ 4	89 %	9.800007
0.23T S/N Protocol: TR 1000/TE 80, FOV 30cm, 256x256, 7mm slice, 7mm gap, 4:16min			

Figure 2. Temperature rise time curve for the MRCI