Signature: © Pol J Radiol, 2014; 79: 268-274
DOI: 10.12659/PJR.890371



Polish Journal of Radiology
www.PolRadiol.com
ORIGINAL ARTICLE

Received: 2014.01.15
Accepted: 2014.01.31
Published: 2014.08.18

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

First Experience with Neonatal Examinations with the Use of MR-Compatible Incubator

Monika Bekiesińska-Figatowska[ABCDEF], Sylwia Szkudlińska-Pawlak[BD], Anna Romaniuk-Doroszewska[BD], Marek Duczkowski[BD], Beata Iwanowska[BD], Agnieszka Duczkowska[BD], Jarosław Mądzik[BD], Hanna Brągoszewska[BD]

Department of Diagnostic Imaging, Institute of Mother and Child, Warsaw, Poland

Author's address: Monika Bekiesińska-Figatowska, Department of Diagnostic Imaging, Institute of Mother and Child, Kasprzaka 17A Str., 01-211 Warsaw, Poland, e-mail: zaklad.rtg@imid.med.pl

Summary

Background: Since 2003, very few publications have described brain examinations using neonatal MR-compatible incubator (INC). The authors present their first experience in these examinations, not limited to brain scans, with the use of an incubator equipped not only with head coil, but also with a coil designed for examinations of the spinal canal and spinal cord as well as the whole body, at the Institute of Mother and Child in Warsaw.

Material/Methods: Examinations were performed in 27 newborns (12 girls, 15 boys). Most of the neonates were prematurely born: 19 (70.4%) were born at gestational age of 23–37 weeks, mean of 30 weeks. They were examined at the corrected age of 26 weeks–1 month, mean of 36 weeks. Body weight of the newborns on the day of the study was 600–4,300 g, mean of 2,654 g. The study was performed with a GE Signa HDxT 1.5 T system with the use of a Nomag IC 1.5 incubator by Lammers Medical Technology Co., equipped with three coils: an eight-channel, phased-array head coil and a twelve-channel phased-array coil for the whole body, consisting of an eight-channel coil integrated in the incubator and a separate four-channel surface coil.

Results: Of the 27 children, 25 (92.6%) required a brain scan. Two children (7.4%) were referred to MRI for assessment of the spinal canal and the abdomen. We compared the results of transfontanelle ultrasound and MRI scans in 21 children. MRI provided significantly more diagnostic information in 18 cases (85.7%); in 3 cases (14.3%), no additional knowledge about the pathology was provided by the exam.

Conclusions: The MR-compatible incubator increases the availability of MRI to newborns, especially premature newborns and those with low and extremely low body weight, for whom MR examinations are necessary to determine the extent of changes, not limited to the central nervous system, as well as to establish prognosis. Dedicated neonatal coils integrated with the incubator permit more accurate diagnosis than the previously used adult coils.

Keywords: Magnetic Resonance Imaging (MRI) • MR-Compatible Incubator (INC) • Neonates

PDF file: http://www.polradiol.com/abstract/index/idArt/890371

Background

The first report regarding magnetic resonance imaging (MRI) in a neonate using a specialist incubator compatible with an MRI system (INC) dates back to year 2003 [1]. If one were to search keywords "MRI", "neonates", "MR compatible incubator", Pubmed contains as little as 15 articles on the subject despite the fact that at least 11 years have passed since the first incubators were used. All published articles pertain to safety issues and brain scans. Thanks to the funds from the Grand Orchestra of Christmas Charity, two first MR-compatible incubators fitted not only with a head coil, but also with a coil designed for examinations of the spinal canal and spinal cord as well as the whole

Table 1. Detailed MRI results in comparison with transfontanelle ultrasonography.

No.	Sex	Corrected age at MRI scan	Ultrasound scan results	MRI results	MRI *vs.* US
1	M	29	IVH II on R, IV on L, cavitation to be differentiated from abscess	Huge cavitation on both sides, post-hemorrhagic foci within cerebellum	+
2	M	Term	Dilated lateral ventricles, dilated paracerebral fluid spaces	Pachygyria, abnormal white matter, thrombosis of superior sagittal sinus and both transverse sinuses	+
3	F	Preterm	IVH II on L, hyperechogenic brain	As in ultrasound + intracerebellar hemorrhage	+
4	F	38	IVH I on R, III on L	+ Polymicrogyria and intracerebellar hemorrhage	+
5	M	1/12	Post-hemorrhagic hydrocephaly	Quadriventricular post-hemorrhagic hydrocephaly	0
6	M	37	IVH III on both sides	As in ultrasound + post-hemorrhagic destruction of both cerebellar hemispheres	+
7	M	38	Hyperechogenic lesion in R frontal lobe	Cerebral and paracerebral hemorrhage in R frontal region, IVH, post-hemorrhagic focus in R cerebellar hemisphere	+
8	F	Preterm	Suspected abscesses	Multiple brain abscesses	0
9	F	39	IVH III on L, hemorrhagic infarction (IVH IV) on R, dilated ventricular system	Paracerebral, cerebral, subependymal, intraventricular (including IV) hemorrhage, post-hemorrhagic cyst hampering outflow from IV ventricle	+
10	M	33	Susp. cerebral hemorrhage and sinus thrombosis	Cerebral hemorrhage	+
11	M	Term	Thalamic vasculopathy	Subcortical h-i lesions on R, cerebral hemorrhage in L parietal lobe	+
12	F	Term	2 × prenatal MRI	MMC closed under skin, scoliosis, costal defect (underdevelopment of L part of the body), 1 ectopic kidney, unicornuate uterus, anal outlet at R labium	Not applicable
13	F	Term	Unremarkable	Unremarkable	0
14	F	36	Unremarkable	Hemosiderin deposits in ventricular choroid plexi	+
15	F	Term	Invisible CC, dilation of L ventrical, cysts at lateral ventricle triangles	Hemimegalencephaly on L, ACC + interhemispheric cysts, azygous ACA, polymicrogyria + subependymal heterotopia to be differentiated from schizencephaly on R	+
16	M	36	Status post IVH II, bilaterally	Unremarkable	+
17	M	41	Unremarkable	Unclear focal lesion in R occipital/parietal region (restricted diffusion)	+
18	M	39	Thalamic vasculopathy	Thrombosis of transverse sinuses and confluence, to be differentiated from infratentorial hemorrhage	+
19	M	Preterm	Prenatal MRI: hydrocephaly, not HPE, cerebellar abnormality	Triventricular hydrocephaly, probably aqueduct obstruction, rhombencephalosynapsis	Not applicable
20	F	Preterm	? Referral: severe birth asphyxia	Diffuse white matter damage with increased DWI in CC, thalamus, lentiform nuclei; cerebral and paracerebral hemorrhage in R occipital and parietal lobes, smaller in R occipital and R frontal [lobes]	?
21	F	43	? Referral: status post SCA	Increased DWI in internal capsule, thalamus, midbrain (L colliculus inferior)	?
22	M	35	Prenatal MRI: CSF-filled encephalocele in parieto-occipital region	Encephalocele in parieto-occipital region with fluid, dysplastic tissue and vessel inside, no brain involvement, bony defect, subependymal heterotopia	+

Table 1 continued. Detailed MRI results in comparison with transfontanelle ultrasonography.

No.	Sex	Corrected age at MRI scan	Ultrasound scan results	MRI results	MRI *vs.* US
23	M	26	Susp. IVH IV on R, difference in neonat. and radiol. opinion regarding the cavitations. Mass effect?	Hemorrhage into ganglionic eminence on R, bilateral intraventricular, subependymal and intrachoroidal hemorrhage, intracelebellar hemorrhage, bilateral cavitations	+
24	M	35	Unremarkable, 2×	Hemorrhagic foci within right brain hemisphere and paraberebrally in L occipital region; severe aphyxia (hyperintense thalami and lentiform nuclei in T1-weighted image) without volume increase and signal increase in DWI; thrombosis of transverse sinuses and confluence	+
25	M	35	Lowered RI in first examination (0.5), normal in second examination (0.7). Otherwise unremarkable	Traces of hemorrhage in posterior ventricle?, lentiform nuclei and corticospinal tracts hyperintense in T1-weighted images; lentiform nuclei, corticospinal tracts, periventricular white matter hyperintense in DWI/hypointense in ADC, susp. cavitation, small thrombosis in confluence and L transverse sinus	+
26	F	Term	Suspected lack of septum pellucidum	Septo-optic dysplasia with R n. II thinned compared to L	+
27	F	Term	Prenatal MRI	Cyst connection to bile ducts and R ovary excluded. Gastrointestinal duplication to be differentiated from mesenteric cyst	Not applicable

Table 2. Comparison of the fields of view in examinations performed using INC and previously-used adult head coil.

Sequence	FOV head coil (adult) [cm]	FOV head coil (INC) [cm]
DWI	24×24	18×18
SWI	26×26	20×20
Other, axial projection	24×18	18×13.5
Other, other projections	24×19.2	18×14.4

body were installed at two neonatology centers in Poland in 2013. The authors present their first experience in these examinations, not limited to brain scans, with the use of one of these incubators at the Institute of Mother and Child (IMC) in Warsaw.

Material and Methods

Within the first several months following installation of INC, 27 neonates (12 girls, 15 boys) were examined at the Department of Diagnostic Imaging of the Institute of Mother and Child by the end of year 2013. Most of the neonates were prematurely born: 19 (70.4%) were born at gestational age of 23–37 weeks, mean of 30 weeks. They were examined at the corrected age of 26 weeks to 1 month, mean of 36 weeks after conception, depending on clinical status and suspected pathology. The body weight of the newborns on the day of the study ranged between 600 and 4,300 g, with the mean of 2,654 g.

All children were examined using a GE Signa HDxT 1.5 T system with an MR-compatible Nomag IC 1.5 incubator by Lammers Medical Technology Co., with temperature and humidity adjustment, fitted with non-magnetic gas cylinders with the capacity of 5L of oxygen at maximum pressure of 200 bar, with non-magnetic gas cylinder pressure reducing valve with flow adjustment in the range of 0–5 L/min, respirator with non-magnetic air pressure reducing valve, pulse oximeter measuring heart rate within the range of 20–300 bpm and partial oxygen pressure within the range of 1–100% and, most importantly, three MRI



Figure 1. MR-compatible incubator.

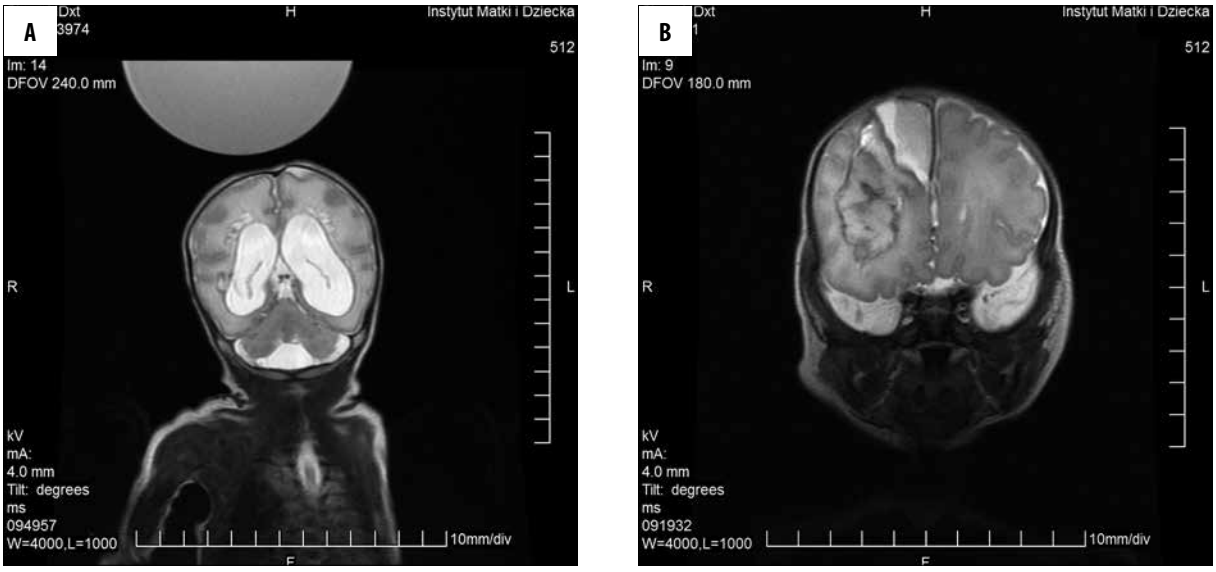


Figure 2. FSE/T2-weighed images in coronal projection. (**A**) Neonate examined using an „adult" head coil with large field of view. Besides the infant's head, the field of view contains almost half of the trunk and partially a phantom to trick the scanner. (**B**) Neonate examined in INC using a dedicated head coil with significantly smaller field of view.

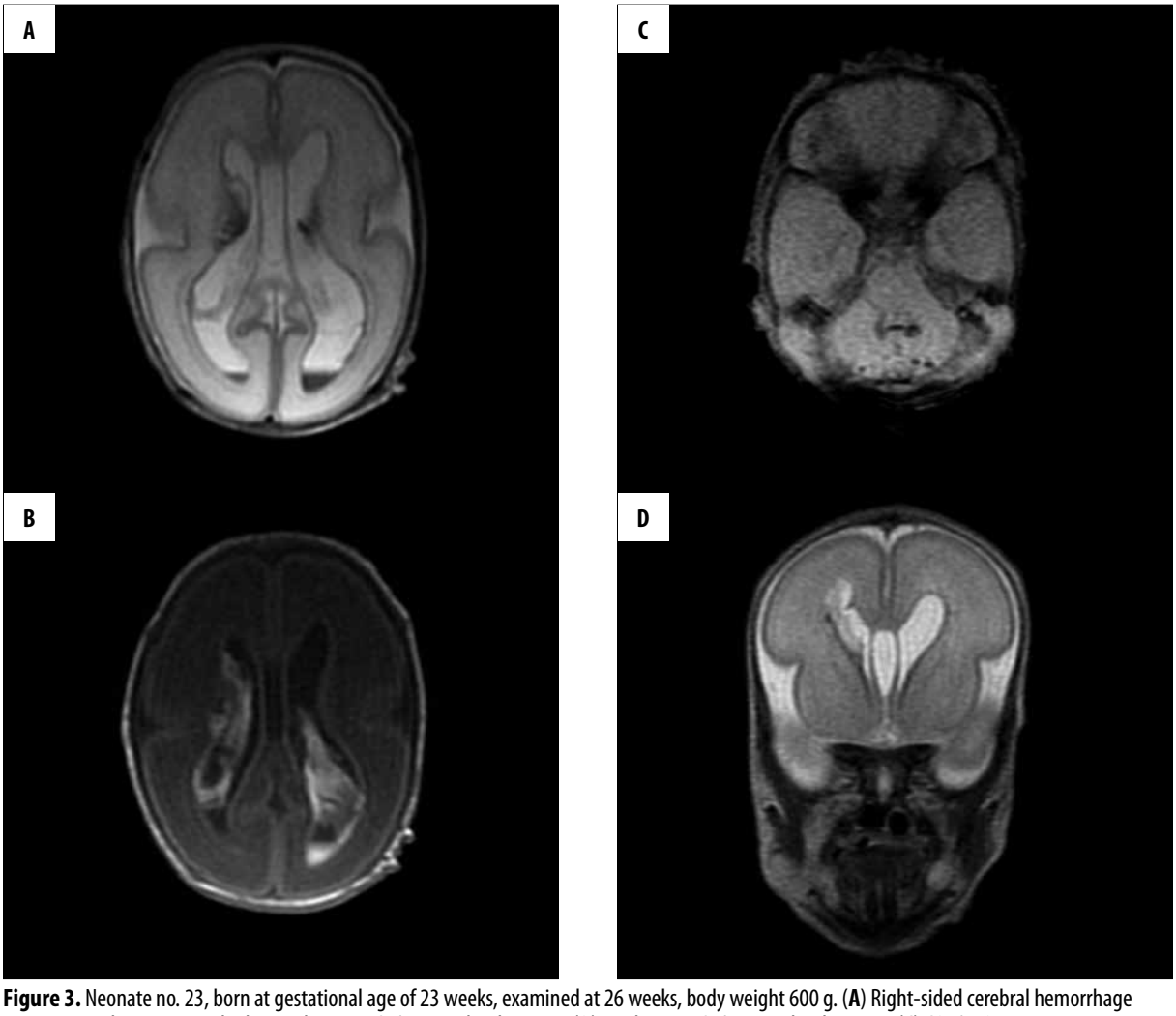


Figure 3. Neonate no. 23, born at gestational age of 23 weeks, examined at 26 weeks, body weight 600 g. (**A**) Right-sided cerebral hemorrhage and intraventricular hemorrhage in FSE/T2-weighted images. (**B**) As above, in SE/T1-weighted images. (**C**) GRE/T2*sequence – post-hemorrhagic lesions within the cerebellum. (**D**) FSE/T2-weighed image in coronal projection. Cavitation above right lateral ventricle.

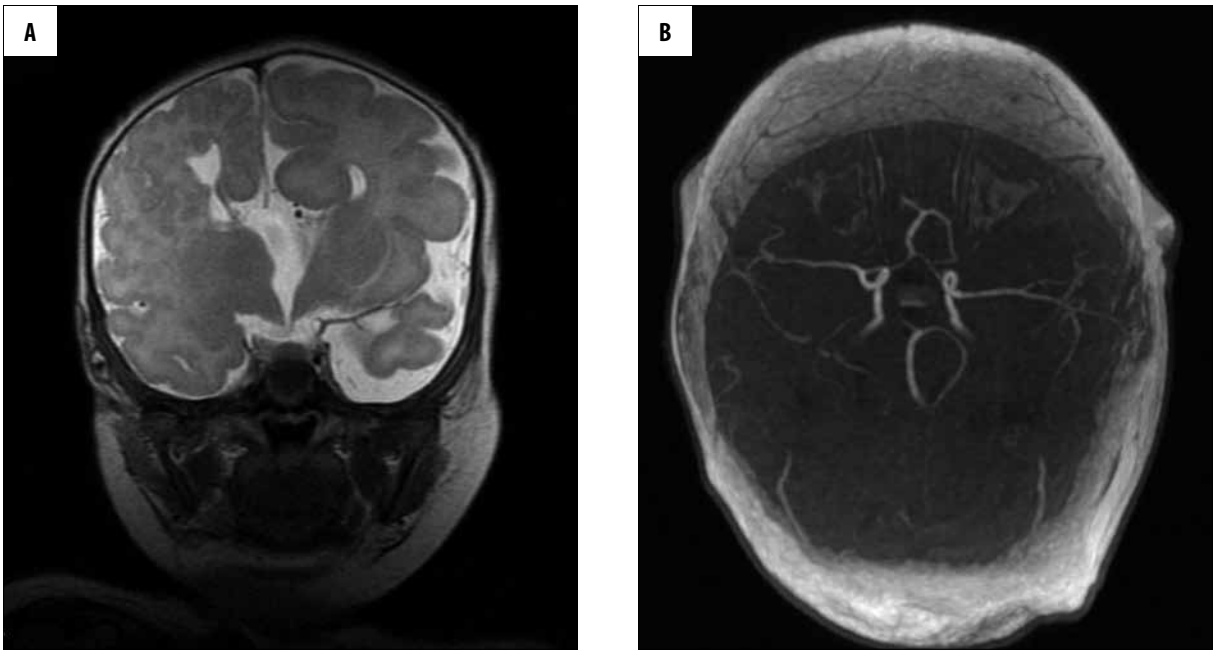


Figure 4. Neonate no. 15, born in term (body weight 3,420 g). (**A**) FSE/T2-weighed image in coronal projection. Agenesis of corpus callosum with typical position of lateral ventricles, polimicrogyria and gray matter heterotopia within right cerebral hemisphere. (**B**) Angio-MRI, arterial setting. Unpaired anterior cerebral artery.

coils: an eight-channel, phased-array neonatal head coil and a twelve-channel phased-array coil for the whole body, consisting of an eight-channel coil integrated in the incubator and a separate four-channel surface coil.

Results

Of the 27 children, 25 (92.6%) required a brain scan. Two children (7.4%) were referred to MRI for assessment of the spinal canal and the abdomen. In 4 cases, scans were performed in children who had undergone prenatal MRI scans; in 2 cases, no transfontanelle ultrasonography (US) results were obtained from the referring sites; in the remaining 21 children, transfontanelle US scans and MR scans were compared. Detailed results of both examinations in the study material are listed in Table 1. MRI provided significantly more diagnostic information in 18 cases (85.7%); in 3 cases (14.3%), no additional knowledge about the pathology was provided by the exam.

There is no quantifiable method to compare the quality of scans obtained using INC, as for obvious reasons, no child could be examined twice, with the "adult" head coil previously used in neonatal studies and with incubator-integrated coils dedicated to neonates with body weights of below 4,500 g. Thus, Table 2 lists only the differences in the fields of view (FOV) in head scans acquired using the INC and the adult head coil. These data provide some insight into the difference in image quality.

Discussion

Safety issues related to transporting neonates for examinations, monitoring vital function and anesthesia are important elements of concern with regard to performing imaging examinations in premature infants. As already mentioned many years ago in the literature [2] and in line with many years of experience at our site [3], there is often no need to anesthetize neonates for MRI scans. The scan is usually performed at baby's natural sleep, after feeding. An MR-compatible incubator (Figure 1), complete with equipment to maintain and monitor vital parameters and allowing to control the temperature and humidity, ensures safe examination conditions for premature infants, particularly lack of temperature differences when removing the baby out of the incubator into the MR facility. Also important is the better immobilization of the child's body by means of Velcro belts and head fixation inserts. Thanks to the use of dedicated coils, INC provides better signal-to-noise ratio, eliminating the need for "tricking" the scanner by introducing into the adult coil a phantom to increase the patient's body volume and mass so as the scanner could detect patient's presence and acquire data (Figure 2A, 2B). Lower fields of view that can be obtained in dedicated coils allow better visualization of image details. Thanks to the above improvements, examination of even the smallest neonates with extremely low body weights became safe and efficient (Figure 3). Literature analysis revealed that the neonate we were able to examine, weighing 600 g, was the smallest baby examined to date. Not all articles reported neonatal body weights; where reported, the lowest values were 1,200 g [4] and 1,400 g [5]. Due to the smaller fields of view and better signal-to-noise ratios we conduct MR examinations in the incubator not only in premature neonates, who unconditionally require these scans, but also in term infants provided their body weight does not exceed the incubator-allowed weight of 4,500 g (Figure 4).

The main indication for MRI scans in neonates, both preterm and term, is suspected brain damage: developmental abnormalities, cerebral premature birth complications and/or perinatal pathologies. MRI scans are an

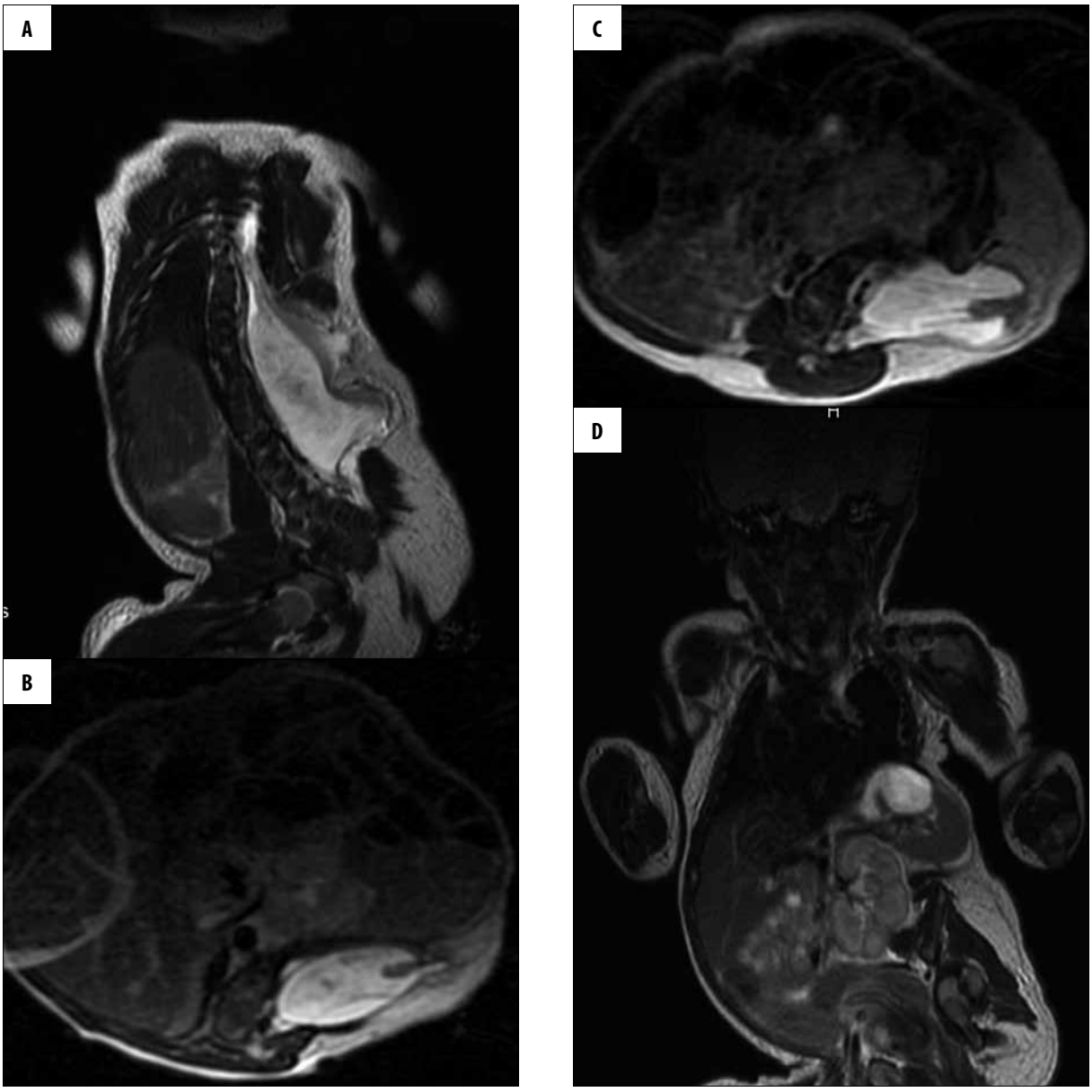


Figure 5. Neonate no. 12. (**A**) Scoliosis, MMC closed under skin in coronal projection (FSE/T2-weighted image). (**B, C**) Images of MMC in axial projection. (**D**) Single ectopic kidney in midline and unicornate uterus.

indispensable tool for the assessment of injuries and establishing prognoses for neonatal growth [6]. As early as 10 years ago, a recommendation was issued to perform MRI scans in preterm infants at dates corresponding to expected delivery, i.e. near the hospital discharge, because of the prognostic importance of such examination. At the same time, the same publication suggested that such examinations should be performed earlier in cases of any neurological symptoms, such as those of acute ischemia, when diffusion-weighted imaging (DWI) allows the assessment of actual involvement of the central nervous system [7]. Polish recommendations regarding these issues are under development at our center.

Also in our study material, brain scans accounted for a vast majority – 92.6% – and demonstrated unquestionable superiority of MR over US scans – 85.7%. The superiority pertained mainly to the assessment of actual extent of the damage, both hemorrhagic and hypoxic-ischemic, particularly to the incidence of cerebellar injury and detection of congenital brain defects. In recent years, the importance of cerebellar function in child's development was determined and greater than expected incidence of cerebellar damage and defects was observed [8,9] (Figure 3C), providing high prognostic value, with traditional transfontanelle ultrasonography incapable of sufficiently visualizing infratentorial structures to ensure their assessment. Summing up literature data and own experience, we may conclude that MRI with its possibilities available today is a method of choice for the assessment of actual involvement of central nervous system in neonates with abnormalities observed in transfontanelle ultrasonography and whose neurological condition is not consistent with correct ultrasound image of brain. It appears that with today's capabilities for

detecting hemorrhages by means of MRI, CT scans can be waived at sites with MRI scanners (Figure 3).

As mentioned in the introduction, all articles on INC published to date pertain only to cerebral scans. However, our small study material included two (7.4%) cases of neonates examined for reasons other than brain-related. In the first case (No. 12) two prenatal MRI scans (first at an outside site, the second at IMC) could not provide the full picture of congenital defects which were ultimately assessed only in the neonatal scan. Myelomeningocele (MMC) was diagnosed in the fetus against the background of significant scoliosis, accompanied by probable diastematomyelia with no hindbrain herniation. Visual evaluation of the infant after birth did not confirm the presence of myelomeningocele, while the scan using INC revealed an MMC of a highly atypical presentation, located under the baby's skin (Figure 5A–C). The classification of vertebral canal defects does not contain such type of a defect, as it includes open, membrane-covered (not skin-covered) dysraphic defects (myelomeningocele, myeloschisis) as well as closed, skin-covered dysraphic defects (meningocele posterior, lipomeningomyelocele, lipomyelocele, myelocystocele) [10]. Although Tortori-Donati, Rossi and Cama proposed a slightly different classification of these malformations [11], our clinical presentation also can not be fitted in to their system: the cited material included 986 children with dysraphic malformations, with MMC being always an open defect accompanied by type II Chiari malformation, and closed malformations, more similar to our case, were associated with subcutaneous lipomas with meningocoeles. The degree of complication in this case explains why it could not have been correctly assessed in prenatal examinations. The spinal defect was not the only developmental abnormality in this child. A single ectopic kidney was correctly diagnosed in prenatal MRI, while the *INC* scan revealed additional uterine defect manifested as unicornuate uterus (Figure 5D); the colon was also tracked to reveal – as confirmed clinically – anal outlet located on the right labium. In the prenatal scans, uterus can be identified as a tiny tissue mass between the urine-filled bladder (hyperintense in T2-weighted images and hypointense in T1-weighted images) and meconium-filled rectum (hypointense in T2-weighted images and hyperintense in T1-weighted images). Uterine cavity, if not filled with liquid as in case of hydrometrocolpos, is invisible and not evaluable. Its abnormal, banana-like shape typical of unicornuate uterus could be observed only after birth In the second case (no. 27), prenatal MRI scan revealed a cyst within the abdominal cavity, with right ovarian cyst suspected as the most probable explanation. After birth, the neonate was referred to abdominal MRI to assess the origin of the lesion and rule out any connection with bile ducts. Standard abdominal scan and MR cholangiopancreatography were performed, excluding any connection of the cyst with bile ducts or ovaries. The diagnosis included gastrointestinal duplication to be differentiated from mesenteric cyst. Surgical procedure confirmed the correctness of the former diagnosis. The above cases allowed to use the whole body neonatal coils and thus to demonstrate their usefulness in imaging small details; according to our knowledge, this is the first report of this type worldwide.

Conclusions

The MR-compatible incubator increases the availability of MRI to newborns, especially premature newborns and those with low and extremely low body weight, for whom MR examinations are necessary to determine the extent of changes, not limited to the central nervous system, as well as to establish prognosis. Dedicated neonatal coils integrated with the incubator permit more accurate diagnosis than the previously used adult coils.

References:

1. Erberich SG, Friedlich P, Seri I et al: Functional MRI in neonates using neonatal head coil and MR compatible incubator. Neuroimage, 2003; 20: 683–92
2. Mathur AM, Neil JJ, McKinstry RC et al: Transport, monitoring, and successful brain MR imaging in unsedated neonates. Pediatr Radiol, 2008; 38: 260–64
3. Cabaj A, Bekiesińska-Figatowska M, Mądzik J: MRI patterns of hypoxic-ischemic brain injury in preterm and full term infants – classical and less common MR findings. Pol J Radiol, 2012; 77(3): 71–76
4. Blüml S, Friedlich P, Erberich S, Wood JC et al: MR imaging of newborns by using an MR-compatible incubator with integrated radiofrequency coils: initial experience. Radiology, 2004; 231: 594–601
5. O'Regan K, Filan P, Pandit N et al: Image quality associated with the use of an MR-compatible incubator in neonatal neuroimaging. Br J Radiol, 2012; 85: 363–67
6. Zupan-Simunek V, Rutkowska M, Bekiesinska-Figatowska M: Predictive value of magnetic resonance imaging (MRI) in cases of acquired brain injury in neonates. Med Wieku Rozwoj, 2011; 15: 385–93
7. Neil JJ, Inder TE: Imaging perinatal brain injury in premature infants. Semin Perinatol, 2004; 28: 433–43
8. Biran V, Bodiou AM, Zana E et al: Cerebellar injury in premature infants less than 30 weeks of gestation. Arch Pediatr, 2011; 18: 261–66
9. Bekiesinska-Figatowska M, Jurkiewicz E, Szkudlinska-Pawlak S et al: Rhombencephalosynapsis – isolated anomaly or complex malformation? Pol J Radiol 2012; 77(3): 35–38
10. Duczkowska A, Bekiesinska-Figatowska M, Herman-Sucharska I et al: Magnetic resonance imaging in the evaluation of the fetal spinal canal contents. Brain Dev, 2011; 33: 10–20
11. Tortori-Donati P, Rossi A, Cama A: Spinal dysraphism: a review of neuroradiological features with embryological correlations and proposal for a new classification. Neuroradiology, 2000; 42: 471–91