Neonatal unit demonstrates the value of 3.0T imaging

Researchers at London’s Queen Charlotte’s Hospital, Hammersmith are at the forefront in developing high-field MRI studies for preterm infants

Neonatal MR imaging of preterm infants presents special challenges including the difficulty of imaging the exceptionally small anatomy of these infants and the fact that they form a notoriously uncooperative patient population. The neonatal unit at the Imperial College Faculty of Medicine, Queen Charlotte’s Hospital, London, already has considerable experience in this area and has recently installed a new Achieva 3.0T system. The unit’s experience so far with the new system indicates that 3.0T imaging of preterm infants can provide a great deal of quantitative data that is potentially of considerable value in diagnosing and treating the conditions that often beset this vulnerable patient group.

Images at the level of the basal ganglia in an infant who suffered a hypoxic-ischemic event and was imaged at 24 days after birth. The T1-weighted image (a) demonstrates abnormal high signal intensity in the lentiform bilaterally (arrow). The T2-weighted image (b) demonstrates abnormal high signal intensity in the lentiform (upper arrow) and thalami (lower arrow) bilaterally.

Dr. David Edwards standing in front of the portrait of Queen Charlotte, the wife of King George III.
The neonatal unit at Queen Charlotte’s was established in 1996 with the aim of creating an environment where even the sickest and smallest preterm babies could be studied. “When studying these babies, there’s always the problem of transporting them away from the intensive care unit to the MRI scanner. This is normally never possible with the sickest babies, the very ones who have the most problems and the ones you want to learn most about,” points out Dr. David Edwards, Professor of Neonatal Medicine at Imperial College, London and Head of Neonatal Medicine at Queen Charlotte’s Hospital.

To address this problem, an MRI scanner was installed within the neonatal unit itself, which meant that the patients could be scanned without ever having to leave the protected environment of the unit. “We found we could examine and treat babies very well in this environment,” says Professor Edwards. “In effect, we set up the scanner as an intensive care unit with all facilities for ventilating, intravenous access and temperature control.”

Previously, the unit relied on a custom-built 1 tesla system with a short magnet to allow them full access to the patient. In late 2006, however, this was replaced by a new Philips Achieva 3.0T. “When 3.0T MRI became available, we realized this would be ideal for imaging the very small anatomies of our patients,” explains Professor Jo Hajnal, Head of the Imaging Sciences Department at Imperial College. “Our experiences with the previous system had already taught us that being closer to the infant was not so important provided you had excellent life monitoring. This allowed us to opt for a commercially available system which also offered other benefits such as easier upgrading. And we chose the Philips Achieva system because of its reputation and because it was the only 3.0T system available at the time that was light enough to be installed on the fourth floor of the building where our neonatal unit is located.”

**Investigating brain injury in newborns**

The babies treated in the unit are predominantly preterm babies or babies born at the right gestation but who are sick, often because of oxygen deprivation during the delivery. The unit’s aim now is to use the 3.0T system to gain a better understanding of how brain injury occurs in these babies, to determine the most frequent types of brain damage in new borns, and to study different kinds of treatment. As part of this last study, the unit plans to use diffusion MRI to assess the efficacy of new drugs designed to prevent brain damage. Functional MRI studies have also started to gain more information about impaired child development.

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Hemorrhagic infarction in preterm infant

Preterm infant born at 25 weeks gestational age and imaged at 32 weeks gestational age. The T2-weighted axial image (a) at the level of the centrum semiovale demonstrates a periventricular hemorrhagic infarction in the white matter (arrow). The sagittal T1-weighted image (b) demonstrates the hemorrhage as high signal intensity.
“We perform a lot of examinations using diffusion tensor imaging and I must say the quality of the brain images and fiber tracking we get at 3.0T is fantastic,” points out Professor Edwards. “There has been some controversy with 3.0T imaging of adult anatomy but I can tell you that our patients, with their tiny anatomy, are naturals for these high-field systems.”

The Queen Charlotte team performs 32-direction diffusion tensor imaging (DTI) to investigate abnormalities in the white matter of preterm infants’ brains. The aim of these investigations, based on TBSS (tract based spatial statistics) postprocessing, is to determine systematic differences between the brain anatomy of preterm and full-term infants. “In a recent study, we made a direct comparison between groups of full-term and preterm infants by performing DTI on the two groups all at term equivalent age,” says Professor Edwards. “We were able to make very effective comparisons of the fractional anisotropy of the infant brains which gives us information about how ordered the white matter is. In this study we found significant differences between the brains of the two groups, which ultimately may lead us towards evaluating treatment options.”

**Studying cardiac function in preterms**

Although the 3.0T system is used primarily for brain imaging studies, the researchers are also studying cardiac function in preterm infants, in particular functional anomalies in babies’ hearts that could lead to brain injury. According to Professor Edwards this is an important avenue to follow as the link between heart function and brain development is not well understood.

“We need to investigate to what extent heart problems can lead to problems in the brain, and for this we need not only cardiac scans but also better measures of brain perfusion,” he says. “There are a lot of techniques for measuring brain perfusion available but many of these involve intravenous injection of contrast agent or nuclear-medicine methods, both of which are technically difficult and unwise to use in preterm babies. For these patients, in particular, a non-invasive MR method such as arterial spin labeling is far preferable for studying brain perfusion and we plan to combine this with cardiac MR scanning to get a better idea of the connection between heart and brain function.” Professor Edwards acknowledges that arterial spin labeling in babies is a challenge but nevertheless he and Professor Hajnal are confident of success with the new 3.0T system.

“The children we deal with are extremely ill and do very badly if their hearts are not working well,” points out Professor Edwards. “For these patients, heart failure is the biggest cause of death, and this may be caused by sepsis or other issues that we don’t fully understand at present. So it’s our perception that gaining a better understanding of heart function in preterm babies will also be an important step towards reducing mortality.”

Despite the technical challenges associated with scanning preterm infants, Professor Hajnal points out that in many ways cardiac imaging at 3.0T is easier than with adult patients. “The small size of the patients’ hearts makes artifacts due to inhomogeneity far less likely than in adult patients. What’s more, the heart rate of neonates is much higher and breathing much shallower, so breath hold is not needed.” he says. “The air spaces in the lungs may sometimes cause inhomogeneity at high fields, but again, this seems to be less of a problem with neonates, probably because their lungs tend to have higher water content and smaller air spaces.”
**Special procedures for imaging neonates**

In a recent study the unit successfully assessed left ventricular function in 10 out of 12 preterm infants with birth weights from 808 to 2200 g. The examinations were performed without sedation or breath-hold, confirming that 3.0T cardiac MRI is feasible for preterm infants and showing that in the future it is likely to be of great value for investigating cardiac function in preterm infants.

Motion artifacts are in fact the greater challenge for brain and cardiac MRI studies and quick sequences are essential. “We often have to stop and start imaging many times, so patience is also an important factor. Our throughput is only around five babies per day but that’s fine in the research environment in which we’re working,” stresses Professor Edwards. “One thing is certain, with the image quality we’re getting, the 3.0T scanner has been an absolute smash hit with the unit, allowing us to be more focused on the critical research questions relating to this patient group.”

**Imperial College Research Radiographer**

Dr. Serena Counsell points out that successful imaging of the neonatal brain requires careful preparation of the infant and close cooperation between radiologist, radiographer and neonatologist. Neonates are imaged during natural sleep following a feed or under light sedation. The Queen Charlotte team uses chloral hydrate administered orally, via a nasogastric tube or rectally. The neonates will then usually sleep through a 30 to 45 minute examination. Severely encephalopathic neonates often require no sedation or they may already be sedated by anticonvulsant medication. The neonates are then closely monitored during scanning with MR compatible pulse oximetry and ECG equipment. In addition, the babies’ ears are plugged with moldable dental putty to protect their developing auditory systems and to prevent the noise of the scan from waking them. Molded air bags or foam is also placed around the head to limit movement. For high signal-to-noise ratio a closely fitting coil is essential.

Besides small anatomy, other challenges associated with imaging neonates are largely due to tissue differences, explains Professor Edwards. “We can’t use the protocols developed for adults for several reasons. The high water content of the newborn body changes the MR characteristics dramatically. In addition, the tissue characteristics of a baby’s brain are very different from that of adult brains and consequently contrasts are different.”

As a result of these differences, the relaxation times T1 and T2 are longer in the neonatal brain than in the adult brain which means it is usually necessary to increase the TR and TE values. Examinations routinely performed by the Queen Charlotte team include T1-weighted scans acquired in the transverse plane. “These are ideal for assessing the basal ganglia and thalami and provide the best views of the posterior limb of the internal capsule,” says Dr. Counsell. “We also perform T2-weighted sequences in the transverse plane. These are better than T1-weighted imaging for identifying early ischemic change, and provide excellent grey/white matter contrast in the very immature brain. We sometimes also perform a T1-weighted sequence in the sagittal plane. In addition we may add a venogram to exclude the presence of sinus thrombosis and differentiate this from subdural hemorrhage, and perform MR angiography of both cerebral and neck vessels, which may be abnormal in focal stroke.”

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