

# MRI in the NICU – Improving Neonatal Care



**MRI in the NICU – Improving Neonatal Care**  
**A Growing Healthcare Issue**  
**A Special Type of Caring**  
**Diagnosis, Treatment and Useful Scans**  
**Full-Scale Scanning for Very Tiny Patients**

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A new approach to MRI inside the NICU

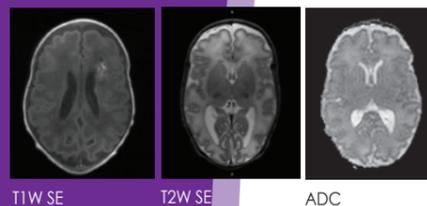


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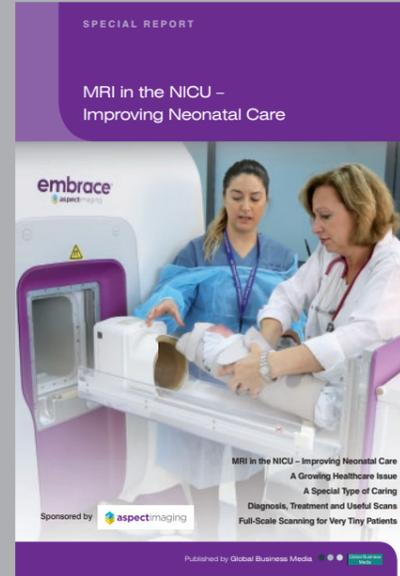


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## Foreword

Babies are the most vulnerable people in our society and so we go to great lengths to protect them from harm or, if they are unwell, to resolve or manage that which ails them. Babies born preterm, with very low weight or incomplete development are especially vulnerable. Fortunately, in recent times we have found a range of ways in which these neonatal babies can be maintained and treated in conditions that are as near safe as we can devise. However, in at least one area of care, that safety often has to be compromised as babies are taken from the neonatal intensive care unit (NICU) to an MRI scanner so that the treating clinicians can obtain the best insight to what is happening inside the neonate's body and head.

This Report looks at the challenges of preterm births, at the particular requirements they have, some ways that have been found to meet those requirements and what developments are afoot to resolve the issue of having to leave the NICU in order to access an MRI scanner.

Our first article comes from a leading Israeli Company in this field, Aspect Imaging, the world's leader in the design and development of compact MR

*John Hancock, an Editor of Hospital Reports Europe, has worked in healthcare reporting and review for many years. A journalist for nearly 30 years, John has written and edited articles, papers and books on a range of medical and management topics. Subjects have included management of long-term conditions, elective and non-elective surgery, wound management, complex health issues, Schizophrenia, health risks of travel, local health management and NHS management.*

imaging and NMR systems for preclinical, medical and advanced industrial applications. It describes a new system that addresses the issue of a neonatal patient getting access to an MRI scan without the risks associated with having to leave the NICU. We then continue to look at the issue of preterm births, the statistics and their impact on patients and clinicians. Camilla Slade then drills down into the specific area of caring for preterm babies and of the specialist facilities and capabilities that have been developed in this area. Peter Dunwell then considers the challenges that clinicians face when identifying and diagnosing conditions in these very small babies with a brief look at what is used to care for them. Finally, we look at the equipment used for an MRI scan, the risks that are attendant on moving a baby from the NICU around a hospital to a scanner and how researchers and developers are now devising and producing MRI equipment tailored to the needs of these smallest and most vulnerable of patients.

**John Hancock**  
Editor

## MRI in the NICU – Improving Neonatal Care

Aspect Imaging

### Introduction

The neonatal intensive care unit (NICU) is a very intense and complex world where, every day, medical staff face unique challenges as they seek the best treatment for the most delicate of patients. To put the challenge in perspective, 1 in 10 of all babies are born premature, amounting to 15 million premature births globally every year. Premature babies can have very poor outcomes, for example, cerebral palsy (CP).

The brain develops rapidly during the 9 months of pregnancy and over the first few months of life. Therefore, it is essential to know what is happening in the brains of premature and term babies, and to make observations as frequently as possible in order to keep up with the rapid rate of brain development.

There are many reasons why babies are admitted to the NICU. In some cases, a baby may have a problem that remains undiagnosed because of the lack of appropriate diagnostic tools. This means that the correct treatment to positively affect the outcome cannot be delivered. Often, full-term babies also have to undergo NICU treatment due to serious conditions such as HIE (Hypoxic Ischemic Encephalopathy).

One of the major difficulties faced by neonatologists is getting an accurate and swift diagnosis, since in newborns, symptoms of neurological disorders – if they appear at all – are not only very subtle, but also shared by multiple conditions. Premature, and indeed, full-term infants can suffer from a wide range of neurologic pathologies.

### The Effects of These Neurologic Pathologies on the Patient and on Society

Early infancy can be a very dangerous period for brain development, during which neurological disorders may occur for a large variety of reasons. Some of these disorders stem from complications during the birth process, such as full-term babies undergoing birth-related asphyxia (deprivation of oxygen to the brain); some stem from prenatal processes, such as the development of central nervous system malformations, while others are caused by

postpartum injury, such as in small, preterm infants with an immature central nervous system. The neurological disorders that occur in infancy can have enormous implications for the long-term and short-term survival of the infant. The more complete the information obtained from a scan, the greater the ability for medical staff and family together, to develop treatment plans, both during the stay in the NICU and regarding continuing treatment following discharge.

In some circumstances, ongoing processes in the brain need to be carefully observed, and in such situations repeated scans within a short period of time are necessary. For example, in the case of hydrocephalus, where a decision has to be made regarding inserting a shunt to drain excess fluid from the brain.

Cerebral palsy is a lifelong developmental disorder that requires long-term care and treatment. The cost of caring for an individual with CP is calculated based on an array of direct and indirect expenses. These include expenses related to medical treatment, as well as home modifications, assistive devices and more.

In 2003, the Centers for Disease Control (USA) estimated that lifetime costs of caring for an individual with cerebral palsy are approximately \$1 million, in addition to normal living costs. When adjusted for inflation, this amount equates to nearly \$1.3 million (as of 2014.)

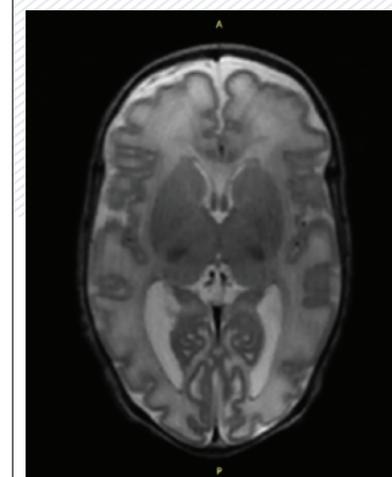
If, by using MRI, neonatologists can make the earliest possible diagnosis, then treatment decisions can be changed, leading to positive outcomes and invaluable savings in both personal suffering for patient and family alike, as well as considerable financial savings for the health sector as a whole.

### MRI: Complementing Ultrasound

To provide a correct diagnosis, it is necessary to conduct a series of tests. Ultrasound (US) has traditionally been the modality of choice for this process and has proved extremely useful in identifying a range of problems. However, there are limitations to what US can identify. This is where MRI steps in. MRI can provide an assessment of brain anatomy, monitor brain development, evaluate the severity and pattern

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**Embrace™**  
Neonatal MRI



#### T2W FSE

TR/TE = 5100/47 ms  
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Resolution = 0.86x0.86 mm<sup>2</sup>  
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*In 2003, the Centers for Disease Control (USA) estimated that lifetime costs of caring for an individual with cerebral palsy are approximately \$1 million, in addition to normal living costs*

of brain injury, monitor the effects of interventions, and eventually may assist in clinical management and offer prognosis information. Ultrasound is a wonderful technology, safe and readily available and is an invaluable tool in neonatal diagnosis. Aspect MRI seeks to complement the benefits of ultrasound by adding high resolution soft tissue imaging to the arsenal of NICU diagnostic procedures.

### Advantages of MRI in Clinical Decision Making

In a retrospective study, the clinical and radiological aspects of 129 neonatal MRI examinations during a 3 year period were analyzed.

MR-based changes in clinical management were initiated in 58% of cases.

The criteria for change in management after MRI examination was: starting or finishing a medical therapy due to the result (anticonvulsive drugs, metabolic supplementation or special diet, antithrombotic or antibiotic drugs), or changes in clinical practice after medications, such as initiation of surgical intervention or postoperative decision-making.

The clinical management changed in suspected diagnostic groups such as thrombosis, metabolic disease, and conditions requiring surgery, such as PHH, trauma and certain malformations and tumors. The most common change in management was an influence on the initiation or termination and choice of long-term anticonvulsive therapy or anticoagulation, operative decision-making or antibiotic treatment.

### The Challenges of Conventional MRI for Neonatal Transportation Systems

MRI is a mature, powerful and highly-developed diagnostic technology. However, there are serious limitations and hazards associated with conventional MRI. It is expensive to purchase, install and maintain. It is difficult to install and operate, requiring a high degree of expertise and specialized facilities. Finally, it is hazardous, especially to neonates who are vulnerable to environmental changes and other hazards such as noise, adverse effects of transport, handling, sedation and so on.

The nature of both premature and term brain conditions means that, in many instances, MRI is clearly indicated as the ideal modality to enable a more accurate diagnosis. In such cases, medical staff have to carefully weigh the benefits of the MRI scan against the hazards of transporting such a delicate patient outside of the NICU. Often, those neonates who most need an MRI scan are those in the greatest danger from the

noise, vibrations, potential collisions, extreme temperature fluctuations and other hazards encountered on route to an external MRI unit. The benefits to both neonates and doctors of scanning inside the NICU are substantial and, it is hoped, would help with the treatment and significantly improve the future quality of life for those babies who are scanned using this system.

Another outstanding feature is the system's convenience and accessibility. Aside from the ease and comfort in which the baby can be placed in the patient bed – which is fully transparent – in the event of an emergency the baby can be accessed and removed in less than 30 seconds. The fact that it is possible to monitor the baby's vital signs, preserve an ideal temperature and observe the baby on the video display throughout the scan, also adds to the safety, usability and effectiveness of the system.

With the system situated inside the NICU, it will be possible to perform high-quality imaging in real-time for immediate diagnosis and treatment. In addition, routine testing will allow medical staff to consult fully with parents regarding the baby's immediate and long-term treatment.

Making fast and accurate diagnoses, exactly in the place where it is needed and in situations when there is no time to lose, is one of the most significant developments in the history of NICU technology.

### The Solution: The Embrace Neonatal MRI System

Aspect Imaging has transformed this remarkable technology with a solution that is accessible, safe and environmentally friendly with practically zero external magnetic field. It is cost-effective, available at the point-of-care and requires only a standard 22m<sup>2</sup> room space. Thus, it can be fully integrated as part of routine medical practice.

Developed over more than seven years by Israeli company Aspect Imaging, which specialises in compact MRI systems whose performance is comparable to that of large conventional MRIs, in July 2017 the Embrace Neonatal MRI system became the first FDA-cleared MRI device specifically for neonatal brain and head imaging in NICUs.

Compact, quiet, self-shielded and able to accommodate a dedicated temperature-controlled incubator-like patient bed, the Embrace can be brought to the patient, removing the need for those perilous journeys to the MRI room, which are the trickiest part of the scanning process to both prepare for and undergo. Preparing a baby for a conventional mMRI and scanning requires anywhere between three and six hours. The baby has to be taken out of the NICU into the MRI



room downstairs in the basement [because conventional MRIs are acutely sensitive to vibration]. In the best-case scenario, this would be in the same building but sometimes it isn't. This journey presents major hazards such as the risk of contamination. Most importantly, though, keeping the baby in the NICU means keeping it close to the equipment that is keeping the baby alive.

Unlike conventional MRI machines, the Embrace is fully enclosed with negligible external magnetic field, which means that it can be used in a standard NICU, no matter what the surrounding equipment is made of.

With superconducting technology as it is today, there are very strong magnetic fields outside conventional MRI machines, so all adjacent equipment must be MR-conditional. With Embrace, however, it is possible to have all types of NICU equipment in close proximity.

Doctors and nurses can also stay with the baby during the scan and, if necessary, pull the baby out in less than 30 seconds, after which everything and everyone needed for treatment or resuscitation is on hand. But if no problems arise, the whole process from bed back to bed can take as little as 45 minutes.

### Aspect's Technologies

The main technological features that set the Embrace apart from conventional MRIs are:

- The magnet – the Embrace system utilizes a 1 Tesla permanent magnet instead of a superconducting magnet, which would require cooling systems.
- Self-shielded system – the Embrace's '5 Gauss line', the perimeter within which the levels of static magnetic field exposure are dangerous, is within the magnet covers. This means that

NICU equipment can be placed near the system and no special MRI room is required.

- The patient bed – babies are placed in a custom-designed patient bed, complete with a customized swaddling accessory, that minimizes movement and maximizes comfort. The incubator-like environment is safe, temperature-controlled and enables continuous monitoring of the infant's vital signs
- The coil – the baby's head is scanned using a transmit-receive head coil designed specifically for infants
- The acoustics – the acoustic noise generated by the Embrace is significantly lower than that of a full body MRI system

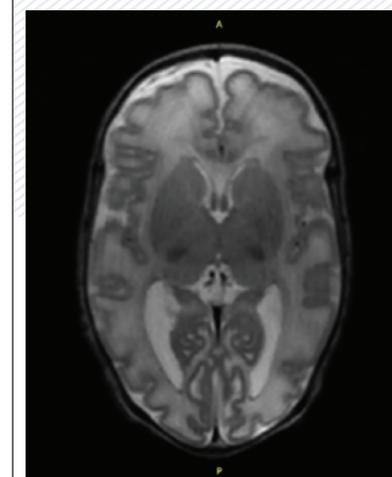
The system has been developed over the course of more than seven years by Uri Rapoport, who has been working in the permanent magnet industry for over 30 years, and a team he's built up over that time. At present, the company has about 160 patents protecting the technology, with another 100 pending.

"It's the accumulation of a lot of knowledge, daring to try, daring to test and daring to show what we can do," Rapoport says. "Over the years, we scaled up from small devices to large devices and did it in a very efficient way. Over the last seven years, we have assembled about 200 versions of this technology magnet and all of them got to spec.

"We have the largest commercially available magnetizer in the world outside the US government and had to invent not only the technology itself but also the ways to manufacture it commercially. We have developed fantastic simulation tools in-house; we didn't buy anything off the shelf. All this means that we can build systems cost-effectively and install them in places that were never feasible before."

A new approach to MRI inside the NICU

## Embrace™ Neonatal MRI



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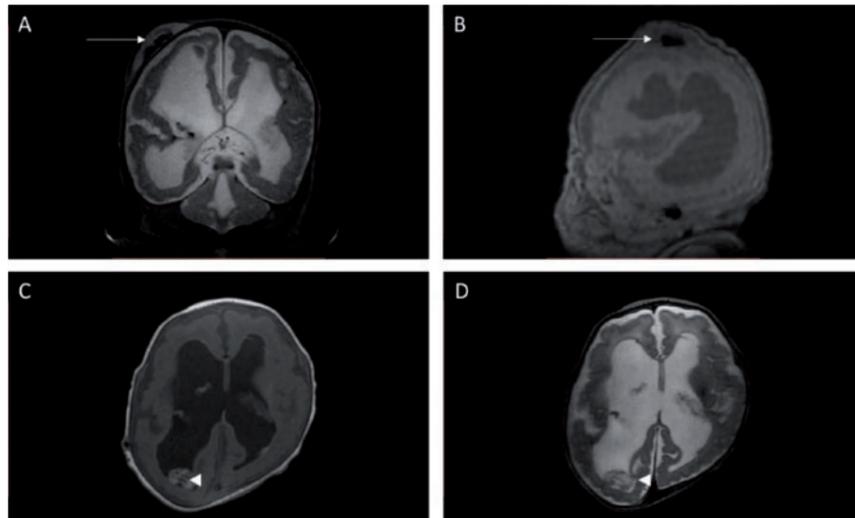
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*MRI is a mature, powerful and highly-developed diagnostic technology. However, there are serious limitations and hazards associated with conventional MRI*



CORONAL T2W IMAGE (A) AND SAGITTAL 3D GRE IMAGE (B) SHOW THE LOCATION OF THE SHUNT (ARROW), AXIAL T2W (C) AND AXIAL T1W SE (D) IMAGES SHOW INTRAVENTRICULAR HEMORRHAGES (ARROW HEAD).

### Pathologies Detected Using MRI

The main pathologies and applications detected using MRI include:

1. GMH (germinal matrix) and IVH (intraventricular hemorrhage)
2. PVL (periventricular leukomalacia)
3. HIE (hypoxic-ischemic encephalopathy)
4. Neonatal asphyxia
5. White matter injury
6. Cerebral hemorrhage
7. PVHI (periventricular hemorrhage infarction)
8. Cerebral infarction (stroke)
9. Sinus thrombosis
10. Deep gray matter injury
11. Brain development

### Two Examples of Embrace Pathology

#### a) Case Study: Patient #23 - Shaare Zedek Medical Center, Jerusalem, Israel

Infant born on gestational age 27.5 weighing 1.28 kg with respiratory distress syndrome (RDS) and post pneumothorax.

Routine US and initial MRI scanning showed post hemorrhagic hydrocephalus; IVH grade 3 or 4. A shunt was placed and subsequent MRI scanning took place one month later, at 38.4 corrected gestation age as part of the Embrace feasibility clinical trial at Shaare Zedek.

MRI images indicate the location of shunt as well as intra ventricular hemorrhages with dilated ventricles.

The Embrace system can be applied for serial scanning for follow up before and after shunt placement.

The advantage of using MRI at this stage is twofold: the effectiveness of the shunt can be

regularly monitored, and the development of surrounding soft tissue can be assessed on an ongoing basis. This information can be used by neonatologists and assist in the diagnostic process

#### b) Case study: Patient #31 - Shaare Zedek Medical Center, Jerusalem, Israel

Infant born at 31 weeks gestation weighing 1.42 kg, with Respiratory Distress Syndrome (RDS) and Patent Ductus Arteriosus (PDA).

US findings showed IVH grade 4 with porencephalic cyst developing in infarct area at the left frontal cortex.

The infant underwent an MRI scan at 36 weeks corrected gestation age as part of the Embrace feasibility clinical trial at Shaare Zedek.

MRI protocol set included the following protocols:

- T1W Spin Echo (Axial slices, slice thickness = 3 mm, in plane resolution = 1 x 1 mm<sup>2</sup>, TR = 600 ms),
- T2W Fast Spin Echo (Axial, Coronal and Sagittal slices, slice thickness = 3 mm, in plane resolution = 1 x 1 mm<sup>2</sup>, TE = 153 ms),
- T1W 3D Gradient Echo (Sagittal, voxel size = 1.5 x 1.5 x 1.5 mm<sup>3</sup>, TR = 20 ms, flip angle 15 deg),
- DWI ADC SPLICE ((Axial slices, slice thickness = 3.5 mm, in plane resolution = 1.5 x 1.5 mm<sup>2</sup>, b = 700, 3 gradient directions).

The advantage of using MRI in this instance is that the stage of injury can be accurately identified, which can assist neonatologists in the diagnostic process. Since IVH in neonates has been linked to subsequent developmental issues, identifying the condition with MRI can assist in developing appropriate treatment protocols regarding the infant's long-term cognitive development.

### The Aspect Vision

The core vision behind Aspect Imaging's revolutionary technology is to make MRI accessible to all without limitations, to make MRI scans as accessible as possible, in any location or environment, without the risks associated with larger, full-body MRI systems.

Aspect's mission is to bring MRI to the point-of-care and to the point-of-need so as to preserve the patient's quality of life. Aspect's goal is to forever change the view that MRI is expensive.

For studying the development of the rapidly-growing neonatal brain, the Embrace system is ideal as it allows for frequent scanning with minimal disruption, so that a clear, longitudinal study can take place that gives as accurate picture of the baby's brain development as possible.

Aspect Imaging's revolutionary, disruptive technology is designed to produce the highest quality images with none of the waste in time, money and valuable healthcare resources that are required by conventional systems. In this way, the benefits of Aspect systems are enjoyed by patient, doctor, hospital and healthcare authority alike.

Aspect's vision is that MRI scanning inside the NICU becomes a standard, routine procedure, and an extremely safe procedure, that can assist in accurate diagnoses and treatment decisions that lead to positive outcomes for both premature and full term babies.

Ultimately, the key advantage of Embrace<sup>®</sup> is that neonatologists will have the ability to scan every baby in their care at least once before leaving the NICU and, where necessary, on a regular and ongoing basis. Embrace is not merely more convenient and safer than conventional hospital MRI systems, it opens up monitoring and diagnostic opportunities that were not previously possible.

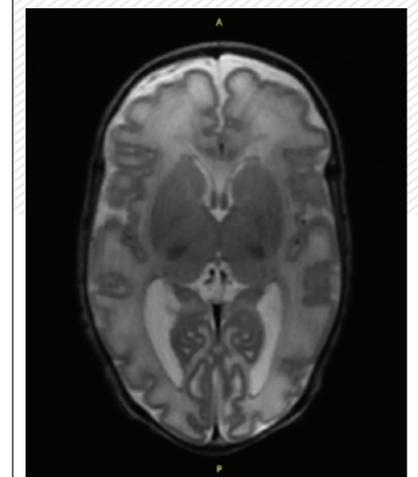
This ability to scan every baby in the NICU holds tremendous advantages for neonatal care and allows for changes in clinical practice after medication, such as initiation of surgical intervention or postoperative decision-making. In addition, Embrace offers prognosis information that may assist in rehabilitation planning.



ASPECT IMAGING EMBRACE NEONATAL MRI SYSTEM

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# A Growing Healthcare Issue

John Hancock, Editor

Preterm births are increasing in prevalence so are becoming an important healthcare issue

*Preterm birth complications are the leading cause of death among children less than five years of age, accounting for approximately 1 million deaths in 2015*

WHEN A birth occurs before 37 completed weeks of gestation, it is defined as premature or preterm. Levels of definition categorize as 'extremely preterm' births that occur at less than 28 weeks and as very preterm between 28 and 32 weeks. From 32 to 37 weeks is categorized as moderate to late preterm.

According to the World Health Organization<sup>1</sup>, it is estimated that, worldwide, 15 million babies are born preterm each year of which some 60,000 are born in the UK; and the numbers are rising. Whether that reflects a growing population or something else is unclear but, come what may, 15 million preterm births is worthy of note. The same report also records that preterm birth complications are the leading cause of death among children less than five years of age, accounting for approximately 1 million deaths in 2015.

And then we come to the more shocking fact that, "Three-quarters of these deaths could be prevented with current, cost effective interventions." What it suggests is that babies born prematurely are vulnerable and, perhaps that's not surprising given that their bodies have not yet fully developed. Also, it's not surprising that the risks are greater the earlier a baby is born.

## Conditions That Can Affect Preterms and Their Treatment

Preterm babies are at risk for a number of lifelong conditions such as developmental delays, hearing problems, sight problems and cerebral palsy. In all of these, early detection and monitoring can improve treatment and management. A compact summary of preterm birth and its potential consequences is available on Wikipedia<sup>2</sup>. Looking for some light in this, *The Guardian*<sup>3</sup> reported a survey showing that "Survival of premature babies more likely now than in mid-1990s..."

All that said, "In some cases, pre-term labor is planned and induced because it's safer for the baby to be born sooner rather than later." That's from the UK National Health Service (NHS) 'Premature labour and birth'<sup>4</sup>. This, the report continues, could be about a health

condition, such as pre-eclampsia, in the mother, in which case, the decision might be on a balance of risk. In that case, the quality of neonatal care and support equipment will be material to that decision.

"Small and sick newborn babies require timely, high-quality inpatient care to survive. This includes provision of warmth, feeding support, safe oxygen therapy and effective phototherapy with prevention and treatment of infections." It might seem that 'BMC Pregnancy and Childbirth'<sup>5</sup> is stating the obvious but this means that, as is often the case, where in the world a preterm baby is born will be a key factor in its chances of survival and, beyond that, quality of life. That will be true for the welfare of any newborn, preterm or not. So, in a country such as England where healthcare facilities are very good, survival rates for preterm infants are improving<sup>6</sup>. The 'healthcare facilities' referred to include the Neonatal Intensive Care Unit (NICU) and, of course, 'survival' might not be the same as quality of life. To understand that, it is necessary to look at the long-term as well as the short-term effects of preterm births. UK HealthCare<sup>7</sup> offers a summary of both the short-term and long-term effects of a preterm birth on the infant. This includes the information that, "The more prematurely the baby is born, the more likely it is that bleeding or other signs of stress will affect the brain." Adding a list of long-term problems associated with brain associated disorders such as behavioral problems, learning difficulties and Attention Deficit-Hyperactivity Disorder (ADHD), concluding that, "Children born preterm are more likely to require early intervention and special education services."

## Longer Term and Other Issues

The reason why NICUs are an important part of the treatment for preterm infants is that the potential and actual long-term health effects are severe and will be costly for the patient and for the healthcare system. So, any improvement that early intervention and treatment can bring is worthwhile. March of Dimes<sup>8</sup> lists a whole range of long-term health effects including, for a baby's brain, lungs, and intestines as well



EMBRACE INCUBATOR

as the sight and hearing problems mentioned above. Also, preterms might be more susceptible to infections throughout their lives. And there is hard evidence to support these effects, including a US study that had run 23 years by 2011 and so had the evidence to plot trends for preterm births right into adulthood – Science Daily, 'Effects of premature birth can reach into adulthood'<sup>9</sup>, which summarized its findings as, "... premature infants are less healthy, have more social and school struggles and face a greater risk of heart-health problems in adulthood."

How clinicians approach preterm births can be categorized in three levels, according to Patient<sup>10</sup>. These are... primary, universal health and lifestyle-related advice given to all pregnant women such as not smoking or consuming alcohol during pregnancy; secondary, which includes specific antenatal care and activities aimed at supporting a healthy pregnancy; and tertiary, aimed more at improving the outcomes for preterm infants once they have been born, but this can include antenatal

treatments for the mother to safely prolong the pregnancy. Looking to more natural interventions, parents of preterm babies are encouraged to spend as much time as possible with them and, to the extent that the machinery and monitors that surround a preterm infant will permit, to hold the baby in order to support as near normal as possible bonding. Mothers are also encouraged to breast feed, again where feasible, because breast milk is best for any baby but especially for preterm births.

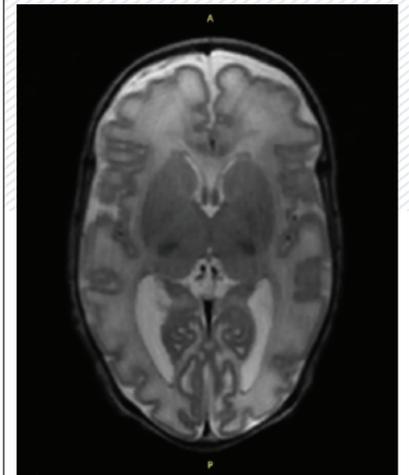
## Ethical Issues

We should briefly touch upon the ethical issues around supporting what might naturally be considered an unviable life. Because parental emotions are always involved, this is probably the most difficult area for clinicians, but the question is always whether prolonging life is in the best interests of the infant. That is not a question for this Report but I have included a brief reference because it is an increasingly important question as the ability to salvage life has improved.

*Potential and actual long-term health effects are severe and will be costly for the patient and for the healthcare system. So, any improvement that early intervention and treatment can bring is worthwhile.*

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## Embrace™ Neonatal MRI



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# A Special Type of Caring

Camilla Slade, Staff Writer

The special challenges and equally special processes that keep preterm babies alive

*Babies born pre-term require highly specialized care in units where multidisciplinary teams can ensure that they receive the best possible technologically advanced care*

IN HIS article, John Hancock set out the facts around preterm births and their consequences. In this article I want to look a little further into some of the challenges that preterm babies and their clinicians can face, but also into how they are cared for and, indeed, how any unwell newborns are cared for.

## Special Type of Care That Needs a Special Place of Care

The overarching term for care at the beginning of life, i.e. from birth, is neonatal care. Bliss is a website aimed at parents of babies born premature or unwell but the first point that needs to be made is that a neonatal unit is not a bad thing. The very existence of such facilities demonstrates how much progress has been made in treating unwell and preterm babies. Bliss<sup>11</sup> describes neonatal units as "... part of hospitals which provide care for babies who are born prematurely (before 37 weeks' gestation), with a medical condition which needs treatment, or at a low birthweight."

Even within that definition, there are levels of care with, at the least intensive end of the spectrum, Special Care Baby Units (SCBU) or low dependency units. Here is where precautionary monitoring, such as of breathing or heart activity, or simple treatments take place – helping with feeding, treating low body temperature or low blood sugar and even some cases of jaundice. For babies who need more care, a Local Neonatal Unit (LNU) can deal with apnoea, feeding through a drip, support with breathing and cooling after a difficult birth. At the highest level of care is the Neonatal Intensive Care Unit (NICU) which is where babies born at the earliest end of the preterm spectrum (less than 28 weeks gestation) or severely unwell for other causes, are maintained during treatment and, often, are kept in an incubator with a vital array of monitoring and treatment equipment to support life.

NICE (the National Institute for Health and Care Excellence) has a guidance 'Neonatal specialist care'<sup>12</sup> which adds some perspective to the statistics, "As a result of increasing rates of fertility and availability of assisted conception, more and more babies in England require

specialist neonatal care each year. In 2007 8, one in ten babies born alive received specialist neonatal care of some sort and this number is constantly increasing. In particular, babies born pre-term require highly specialized care in units where multidisciplinary teams can ensure that they receive the best possible technologically advanced care..."

## Quality Control and Improvement, and the Risk of Legal Action

It is a complex area of medicine and, with a combination of that complexity and the vulnerability of patients, the NICU is more susceptible to accidental error than some other parts of the healthcare system. *The Journal of Perinatal and Neonatal Nursing*<sup>13</sup> explained that, "The unique aspects and the complexity of the neonatal intensive (NICU) environment, in addition to the vulnerability of the neonatal population increase the risk for medical errors." In 2017, the *Journal of Pediatric and Neonatal Individualized Medicine* published 'Focusing on patient safety in the Neonatal Intensive Care Unit environment'<sup>14</sup> which included among its conclusions that NICU staff should "... implement best practices, and support safety culture, maximizing efforts for reducing errors." One problem with this is that, for some procedures, NICU patients might have to leave the NICU and, away from that safety culture, will be more vulnerable. For a final word on quality, Elsevier's 'The case for quality improvement in the Neonatal Intensive Care Unit'<sup>15</sup> concludes that quality improvement can be achieved by addressing those methodologies that give rise to risk (author's synopsis).

One real challenge faced by clinicians in this area is identifying and diagnosing medical conditions in babies who are very small, not robust and unable to tell the examining clinician how they feel. MSD Manual sets out some of the problems in its 'Overview of General Problems in Newborns'<sup>16</sup> which explains some of the ways in which clinicians might be able to diagnose illness in a small baby such as one that is preterm. The advice is that, following routine tests after birth, "Additional tests, including blood tests, x-rays, ultrasonography, and others may be done



when babies have specific problems or have abnormal findings on the routine tests." One thing of which clinicians must be increasingly aware is the possibility of legal action whenever anything might go wrong, whether or not any negligence was involved. So, any steps to improve the quality of a NICU will be of value first to the patient and their family but also to the hospital where the NICU is located.

## The Long View... Both Ways

We've considered the equipment and some of the risks involved with neonatal care and, especially, the care of preterm or premature babies; but what about the care of those particularly vulnerable patients? If you're interested in the long history of this specialism, then Penn Nursing<sup>17</sup> has a comprehensive paper charting progress from the first neonatal incubators in France in the late nineteenth century right up to the present day.

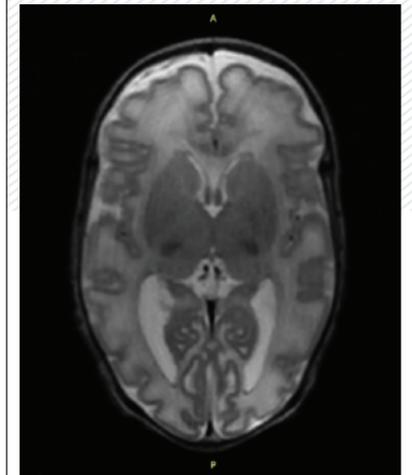
But progress can give rise to its own challenges and one challenge for modern neonatal care is that, if the incubator and NICU are keeping a baby alive, how can that care be maintained if the tests or treatment they need are outside of the unit or require their removal from the incubator and its accompanying monitors and treatments? Peter Dunwell will address that issue in more detail in the next article, but I include the mention in the context of best practice for neonatal care.

*Reproductive Health* in its paper 'Born Too Soon: Care for the preterm baby'<sup>18</sup> sets out a number of standards for care and points out some of the consequences of poor care including, "An important but under-recognized issue for all countries is that of disability for survivors of preterm birth." This matters, not only for the patient but also for the health care system which will have to pick up the cost of long-term care and treatment for any disability.

*An important but under-recognized issue for all countries is that of disability for survivors of preterm birth. This matters, not only for the patient but also for the health care system which will have to pick up the cost*

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# Diagnosis, Treatment and Useful Scans

Peter Dunwell, Medical Correspondent

Before a neonate can be diagnosed and treated, it's important to find out what is happening inside their body and head

Diagnosing health issues in children is often complicated by their inability to explain how or what they feel. So NICE offers clinicians a number of pathways

## Care and Diagnosis of Neonates and Vulnerable Infants

Understandably, the diagnosis and care of newborn babies, preterm or full term, is a matter of importance. In the UK, the National Institute for Health and Care Excellence (NICE) publishes a number of guidance papers including on 'Neonatal infection'<sup>19</sup>. It sets a quality standard that, "covers preventing infection in newborn babies... and treating newborn babies with suspected or confirmed infection. It includes when to give antibiotics to prevent and treat neonatal infection." That part about preventing neonatal infection is important because, from a combination of incomplete development resulting from their preterm birth and, sometimes, the health issues that caused the preterm birth, babies who require neonatal care are particularly susceptible to outside infections. For that reason, they are usually kept in an environment as near sterile as possible. The problem is that, unless all of the interventions, tests and monitoring they require can be brought into that environment, then they will have to be taken out into the wider hospital for some of the tests they require. A section of the NICE guidance 'Treating and caring for people in a safe environment and protecting them from avoidable harm' is about "healthcare associated infection".

In a similar way, the Royal College of Paediatrics and Child Health (RCPCH), in its 2018-2021 strategy<sup>20</sup>, focuses on the specialist issues that arise when caring for babies and children with the aim to, "Improve UK child health and wellbeing and reduce unnecessary illness progression and avoidable death through health promotion, illness prevention activity, early and appropriate intervention so that UK outcomes match the best in the world." Diagnosing health issues in children is often complicated by their inability to explain how or what they feel. So NICE offers clinicians a number of pathways when dealing with 'Infants and neonates'<sup>21</sup>.

## Treatment of Neonates and Vulnerable Infants

Treatment for infants and neonates is also different, having to take into account not only their developmental problems but also that the very equipment that keeps them alive makes normal physical contact more difficult. The World Health Organization (WHO) offers specific recommendations on 'Care of preterm and low-birth-weight newborn [infants]'<sup>22</sup> with a number of techniques designed with these babies in mind such as 'Kangaroo Mother Care' but also clinical interventions with a number of treatments aimed at conditions often encountered with neonates.

Also, going back to the NICE pathways (above) the section on 'Neonatal specialist care (QS4)' offers clinicians a number of sources to draw on when treating health conditions in neonates.

## Technologies and Scans

### Ultrasound scan

"A head ultrasound is a safe and painless test that uses sound waves to make images of the brain." That description, from *Kids Health*<sup>23</sup>, continues to explain the limitations of the technique, i.e. that ultrasound works well on soft tissue but that bones block the passage of the ultrasonic waves that give the test its name. That limits the test to babies where the fontanel is still open. But the test is used for "Premature babies who require intensive care frequently have head ultrasounds to rule out neurological complications of prematurity..."

### MRI scan

A more efficacious system is Magnetic resonance imaging (MRI) which uses a large magnet and radio waves to look at organs and structures inside the body: MRIs are very useful for examining the brain and spinal cord. That is why they are helpful when examining preterm babies for any signs of brain disorder, including cerebral



palsy. The UK National Health Service (NHS) offers an 'Overview' of the MRI scan<sup>24</sup>. However, MRI scanners have, until recent times, been very large pieces of equipment that are often housed in the basements of hospitals in order to give them the most solid possible base and avoid vibrations that might distort the result.

In fact, *Radiology Info*<sup>25</sup> includes a section specifically on pediatric MRI which is a system well suited to identifying the early signs of health issues which, if left undetected or untreated could develop into life changing or life limiting conditions. When imaging of a child's brain and spinal cord is needed, MRI is useful because of its ability to see through the skull and the bones of the skull and spine without radiation. One condition, already mentioned above, is cerebral palsy where an MRI scan is one often used as a means of detection. As the NHS page on Diagnosis of cerebral palsy<sup>26</sup> explains, an MRI scan produces "a more detailed image of the brain" to help clinicians identify the type of brain damage that can be a sign of cerebral palsy and to diagnose the condition earlier to allow treatment to start sooner.

*Magnetic resonance Insights*<sup>27</sup> has produced a paper on use of MRI with pediatric patients, identifying some of the advantages over other systems of using MRI with infants and children

but also identifies some of the drawbacks, including, "the potential need for sedation or anesthesia and the limited availability of MR equipment tailored to pediatric use outside specialized centers." (author's emphasis). With very unwell preterm infants, it might well be that they are sedated anyway but the issue of where the MRI scan is located can mean that the patient has to be taken away from the relative safety of the NICU and its range of equipment. To get some idea of how much equipment is involved, *March of Dimes* offers a helpful list of Common NICU equipment<sup>28</sup>, including the 24 most often encountered.

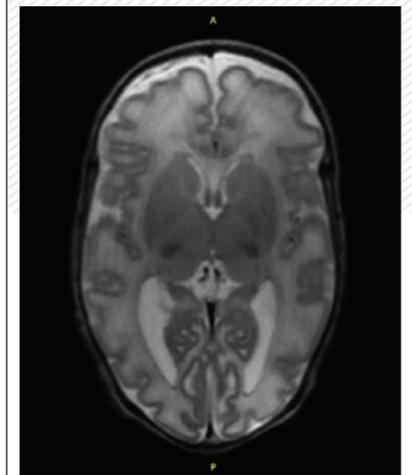
## The Risks Associated with Transportation

It is the need to take the vulnerable preterm infant away from all that equipment, for what might be up to an hour, and out into the more threatening environment beyond the controlled NICU that makes the use of standard MRI scans most problematical for very small and ill patients. Given these issues, any development that can mitigate the need to put vulnerable neonates at risk in order to give them access to the best scanning system for their condition will be a welcome development. In the next article, we'll look at how such developments are progressing.

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# Full-Scale Scanning for Very Tiny Patients

John Hancock, Editor

Developing the MRI to better meet the needs of neonates

*Providers use lots of equipment in the NICU to help take care of your baby. Each piece has a special purpose in your baby's treatment*

AS PREVIOUS articles have suggested, while the MRI scan might well be the best technology for detecting problems, especially with the brain, in any baby, if the scanner is located, as many are, in a hospital basement, getting the baby to the scanner will involve a journey through the hospital. Knowing the incidence of hospital acquired infection (HAI), there is a degree of risk for anybody moving around in a hospital environment but, for those babies who are in incubators within the NICU, that risk is much higher, given their underlying weakness. Better Health 'Infections in hospital – reduce the risk'<sup>29</sup> sums it up, "All people admitted to hospital are at some risk of contracting an HAI... Some people are more vulnerable than others. These include: very young people – premature babies and very sick children..." But the risk is more than just HAI.

## Taking a Preterm Away from the Safe Environment

Preterm babies are kept in an incubator which Very Well Family<sup>30</sup> explains, "... is a self-contained unit roughly the size of a standard crib equipped with a clear plastic dome... the incubator ensures the ideal environmental conditions by either allowing the temperature to be adjusted manually or providing auto-adjustments based on changes in the baby's temperature. An incubator also protects the [preterm] from infection, allergens, or excessive noise or light levels that can cause harm." Added to that, The NICU employs a host of other equipment vital to the maintenance of preterm babies as March of Dimes<sup>31</sup> explains, "Providers use lots of equipment in the NICU to help take care of your baby. Each piece has a special purpose in your baby's treatment." The explanation is followed by a long list of those items.

Taking a baby away from the ICU to an MRI scanner is a journey fraught with challenges. It means either removing the infant from the incubator and/or moving the incubator. In either case, it means taking all of the equipment out

of the NICU to where the scanner is housed, or it means removing the baby from that vital equipment for what might be a lengthy journey to and from the scanner plus the time required in the machine. Bearing all that in mind, it would be of benefit to the preterm infant but also to the NICU and to the healthcare system to be able to obtain the advantages of a scan while avoiding all of that risk.

## Better and Safer Solutions

The problem is that MRI scanners are usually so large that the patient has to be taken to the scanner but, if a scanner can be designed only for very tiny patients, i.e. preterm and low weight infants in an NICU, then much of the risk associated with transporting a patient out of the controlled environment of the NICU will be avoidable. In early 2017, Wellcome<sup>32</sup> reported on an 'MRI scanner for tiny babies' that had been developed "in a collaborative effort between Sheffield Teaching Hospitals NHS Foundation Trust, the University of Sheffield, Wellcome and others. Explaining one reason, in addition to the problems of transport, for working on the development, Paul Griffiths, Professor of Radiology at the University of Sheffield, stated; "Babies, particularly with brain problems, are unstable – they can stop breathing or their blood pressure can change in an unpredictable way. If that happens it is useful to have neonatal staff who are used to that situation in such close proximity, which will improve safety."

In a similar development, Med Gadget<sup>33</sup> reported in mid-2017 on, 'Embrace Neonatal MRI System Cleared to Stay Inside Neonatal ICUs'. As well as the safety argument put forward for the Sheffield machine, Med Gadget adds, "Because it's a fully contained system, unlike traditional MRIs it does not require an exclusion zone nor is there a need to have additional walls shielding the radiofrequency signal." Other journals, including the *American Journal of Roentgenology*<sup>34</sup>, looking more from a consideration of the technology, have found that a small MRI can effectively do the job required in imaging neonates.



EMBRACE WITH NICU EQUIPMENT

For those charged with choosing a neonatal MRI system, the consideration has to be, can the system deliver a comparable quality of result to that achieved by a standard MRI scanner while avoiding the risks attendant upon having to transport the neonate at least to another location within the hospital or, at worst, to another site entirely?

## The Future for Neonatal MRI

As well as developing smaller and enclosed MRI units that can be used within the NICU, researchers are also addressing other issues with MRI scanners. One issue is the noise which, as a group of academics and researchers who published 'A novel acoustically quiet coil for neonatal MRI system'<sup>35</sup> explained, "has the potential to elicit physiological distress and impact development in preterm and term infants." continuing to set out the research and results for an acoustically quiet MRI scanner.

At Cincinnati Children's Hospital Medical Center, researchers have adapted an adult orthopaedic MR system to serve as a whole body system

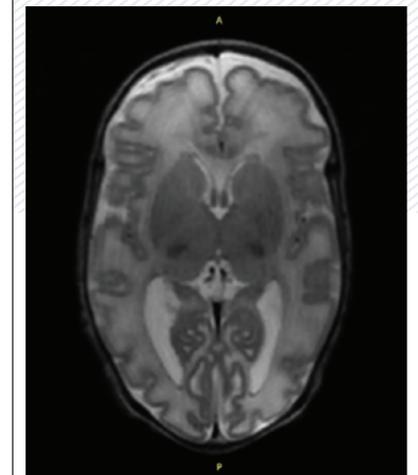
to be used with neonates. The brief article<sup>36</sup> on the research concluded: "The modified system enables state-of-the-art imaging of the neonatal brain, chest and abdomen with a high degree of safety and diagnostic imaging quality. S/N enhancements and parallel imaging enabled by these changes result in improved image quality and/or reductions in scan time, beyond what is currently possible on conventional MRI scanners."

There seems to be activity in this area of research and we can only welcome something that will improve the life chances and life quality for babies born too early for their natural development to have prepared them for the world outside of the womb. These are uniquely vulnerable patients for whom any process that involves lowering the levels of support and protection that they receive in the NICU entails risks from deterioration in their condition to death. It is therefore to be applauded that researchers are tackling the issue of getting MRI scans completed for neonatal infants without the risks attendant on having to move patients out of the NICU.

*Babies, particularly with brain problems, are unstable – they can stop breathing or their blood pressure can change in an unpredictable way. If that happens it is useful to have neonatal staff who are used to that situation in such close proximity, which will improve safety*

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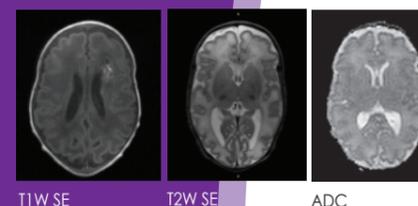


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