Congenital Heart Disease (CHD) is a significant cause of infant death and accounts for between 3-7.5% of deaths in infancy in the developed world (Singh et al., 2014). For this reason, screening for CHD is included in the newborn physical examination (NPE) that occurs within 72 hours of birth. This article will review the limitations of screening for CHD at the NPE, within the context of the UK screening programme. Reference will be made to relevant fetal and neonatal physiology. In addition, the usefulness of additional screening tools, such as pulse oximetry and four limb BP will be considered, in the light of recent research evidence.

CHD can be defined as:

“A heart condition that results in an abnormality of the actual structure of the heart or of its function, which is present from birth.” (Peterson, 2003)

The exact incidence of CHD is debated since research studies from the past 20 years have presented a variety of statistics. Hoffman and Kaplan (2002) gave an incidence of 12 to 14 per 1,000 births, whereas Patton and Hey (2006) stated a lower incidence of five to eight per 1,000 births. More recently, Public Health England (PHE) cited the overall incidence of CHD as four to 10 per 1,000 births (PHE, 2016). The variation in statistics for CHD stems from the fact that it is a term that covers a wide range of defects. These vary from minor and clinically insignificant anomalies to those that require urgent treatment to preserve life (Mellander, 2013).

The main aim of screening for CHD is to detect those defects that are clinically significant. To provide clarity, PHE has categorised significant CHD in the following ways:

Critical congenital heart disease (CCHD):

“All potentially life-threatening duct dependent conditions and those conditions that require procedures within the first 28 days”.

Major congenital heart disease (MCHD):

“All conditions that require invasive interventions within the first year of life.”

(Public Health England, 2016, p. 14)

## Screening for congenital heart disease

The UK National Screening Committee (UK NSC) is an independent expert agency that makes recommendations on population screening to all four of the countries that make up the UK. In England, the NSC advises PHE (Hall and Elliman, 2003; UK NSC, no date).

The current guidance includes three staging points in the screen for CHD in England:

 Scotland and Wales.

* The 20 week anomaly scan
* The newborn physical examination (within 72 hours of life)
* The infant physical examination (at six to eight weeks of life).

The newborn and infant physical examinations are known as the NIPE, (PHE, 2016; Powell, 2019).

Although there has been some improvement over recent years in the antenatal detection of CHD, the sensitivity of the 20 week anomaly scan is low and performance varies greatly across the UK. Overall, the antenatal detection rate for CHD has been quoted as between 20 and 50% (Knowles and Hunter, 2014; Singh et al., 2014). Issues relating to the low detection rate are complex and include persistent challenges with the recruitment of skilled personnel as well as a lack of regulation of the standards required for ultrasonographers (NHS England, 2014). Therefore at least 50% of cases of CHD are undetected at the time of birth.

Research conducted over the past 25 years has found that the NPE also misses a significant number of newborns with CHD. Up to 50% of affected newborns are sent home, undiagnosed, with their mother (Knowles and Hunter, 2014). Among those newborns will be some that are affected by the rarer forms of CCHD. The overall incidence of CCHD is between one and three per 1000 (Mellander, 2013; Bruno and Havrenek, 2015; Eckersley et al., 2016). However such forms of heart defect carry high levels of morbidity and mortality. The problem is that a newborn with CCHD can be asymptomatic in the early hours, for physiological reasons that will be discussed later in this article. Such cases pass through the NPE undiagnosed, only to present later in an accident and emergency department in a state of collapse (Ewer, 2014; Eckersley et al., 2016). Seminal work by Wren et al (2008), who conducted a large retrospective study of a northern region of England, found that 30% of CCHD cases were missed by the NPE, and of those, 5% were only diagnosed at post-mortem.

The cardiovascular screening examination performed at the NPE is made up of observation, palpation and auscultation (Vargo, 2016).

Table 1 gives the exact components of the cardiovascular assessment, as described by PHE (2016, p. 6):

### Table 1: Components of the cardiovascular assessment at the NPE

|  |  |
| --- | --- |
| Observation | Respiration: rate and work of breathingGeneral toneSize and shape of chest/symmetry of movementColour: central and peripheral |
| Palpation | Pulses: brachial and femoral for strength, rhythm and volumeCapillary refill+/- thrillAbdominal palpation |
| Auscultation | Auscultation of heart sounds in five areas for presence of murmur/quality of heart sounds:Second intercostal space; right: aortic areaSecond intercostal space; left: pulmonic areaLower left sternal border: tricuspid areaApex: mitral areaBetween scapulae: coarctation area |

## Newborn physiology and the detection of CHD

There are physiological reasons why the detection of congenital heart disease at the NPE is problematic. The newborn cardiopulmonary circulation has a dynamic nature during the early hours of life, as the newborn cardiopulmonary system transitions to that of extrauterine life. (Kemper, 2011).

The ductus arteriosus is an anatomical connection that is required for fetal circulation between the pulmonary artery leaving the right ventricle and the aorta leaving the left ventricle. It exists due to the physiological requirement for most of the fetal blood to bypass the lungs until after birth (Tucker Blackburn, 2018). Following birth, there is functional closure of the ductus arteriosus as it constricts gradually in response to the rise in newborn blood oxygen levels, which occurs with the onset of breathing (Forsey et al., 2009). Permanent, anatomical closure of this duct then follows several weeks later (Tucker Blackburn, 2018). The timing of functional closure can vary between infants. Bedford and Lomax (2015) stated that the ductus arteriosus begins to constrict in the first few hours after birth, but that it can take up to 96 hours to completely close. The initial patency of the ductus arteriosus is an important reason for the failure to detect the types of CCHD that are known as duct dependent defects (Knowles and Hunter, 2014). This is because the open ductus arteriosus allows the mixing of the pulmonary and systemic circulations. This permits partially oxygenated blood to bypass any life-threatening cardiac malformation, so that the newborn remains asymptomatic. However, once the ductus begins to close, the newborn will quickly deteriorate. The problem lies in the fact that, all too frequently, this occurs after transfer home (Mellander, 2013; Singh et al., 2014).

Another important physiological feature to consider is the gradual expansion of the newborn lung fields after birth. During intrauterine life, pulmonary circulation is in a state of high vascular resistance. Following birth, with the newborn’s first intakes of breath, a much bigger volume of blood begins to circulate through the lungs. In this way, the pulmonary vascular bed gradually expands, with a corresponding decline in pulmonary vascular resistance. The effect of this is that there is a drop in pressure within the right side of the heart and an increase in pressure within the left side of the heart (Mannarino et al., 2013). This increased left to right shunt can then reveal heart murmurs that were previously inaudible during the early hours of life. Depending on the timing of the NPE, this can mean that the heart murmur will be missed (Bedford and Lomax, 2015; Vargo, 2016).

The persistence of fetal structures after birth, such as the ductus arteriosus, are also said to be one of the reasons for the presence of so called “innocent” heart murmurs (see Table 2) that subsequently disappear within the first few days of life, when closure occurs (Gandhi and Sreekantam, 2011). Newborns with this sort of murmur do not usually have CHD, but their presence may delay transfer home of the mother and baby, due to the need for review by a senior neonatologist (Shenvi et al., 2013).

## Heart sounds and heart murmurs in the newborn

Auscultation of the heart is a clinical skill that is fundamental to the cardiovascular assessment at the NPE (PHE, 2016). Two heart sounds are typically described in the literature, known as heart sound 1 (S1) and heart sound 2 (S2) (Mannarino et al., 2013).

The origins of heart sounds heard during auscultation are complex, but are said to follow the closure of the heart valves during systole and diastole. As described by Mannarino et al., 2013), S1 is associated with the closure of the atrioventricular valves (mitral and tricuspid) at the onset of ventricular systole, while S2 is associated with the closure of the semilunar valves (aortic and pulmonic) at the end of ventricular systole. Diastole then occurs between S2 and S1.

Heart murmurs heard during cardiac auscultation are additional sounds to S1 and S2. A heart murmur can be defined as:

“The sounds produced by the vibrations caused by turbulence of the blood flow within the heart.” (Naik and Shah, 2014, p. 2)

The presence of a heart murmur in the newborn can be described as either *innocent*, that is, caused by the transitional physiology already described, or *pathological*, that is, caused by clinically significant congenital heart disease. In order to aid the clinician who is attempting to describe the murmur that he or she hears, murmurs have been categorised according to the level and quality of sound and timing. There is broad agreement in the literature in relation to this grading, and their relationship with CHD.

### Table 2: The categorisation of heart murmurs.

Frommelt et al (2004, p.1026;).

|  |  |
| --- | --- |
| Sound level and quality | Grade 1: Soft, barely audible, need quiet environment, usually innocent.Grade 2: Easily audible but still soft, often innocent.Grade 3: Loud and instantly recognisable, when placing stethoscope on chest, can be harsh, often pathological.Grade 4: Loud, harsh sound, always pathological.Grade 5: As 4, can hear with edge of stethoscope on chest.Grade 6: As 4 and 5, can hear without placing stethoscope on chest. |
| Timing | Can be early systolic, pansystolic, diastolic or continuous.Diastolic murmurs are always pathological in the newborn, continuous murmurs are often pathological. |

It is usual practice for the presence of a heart murmur in the newborn to trigger referral for a diagnostic echocardiogram. Echocardiography is viewed as the most appropriate diagnostic test, and its introduction has revolutionised the care pathway for babies with suspected CHD, as it is non-invasive yet highly accurate when performed by skilled personnel (Singh et al., 2012). However, it is not always available in UK hospital trusts, and this can have an impact on the time interval between the identification of a heart murmur at the NPE and the diagnosis of congenital heart disease. This delay can be as much as several weeks (Shenvi et al., 2013).

Therefore, once a murmur has been auscultated at the NPE, it is important to make a judgement as to whether the murmur sounds pathological or innocent. Newborns with murmurs that are deemed innocent by experienced practitioners can be reviewed as outpatients, whereas those with a pathological sound require more urgent investigation. Common practice in the UK is that the newborn with a heart murmur at the NPE will remain in hospital until after 24 hours in order for the heart sounds to be reviewed by a senior neonatologist (Shenvi et al., 2013). This allows time for murmurs related to transitional physiology to disappear, whereby further investigation becomes unnecessary. It may also allow sufficient time for clinical signs of CCHD to present in the baby, while still an inpatient in the acute health care setting (Eckersley, 2016).

Two further screening tests are often performed when echocardiography is not immediately available. The first is four limb blood pressure. This test involves the sequential measurement of blood pressure on each of the newborn’s limbs. A difference of 15mmhg or more between the upper and lower limbs constitutes a positive screen for CHD (Boelke and Hokanson, 2014). In a recent survey it was found that 76% of hospitals in the UK were performing this test following the auscultation of a heart murmur in the newborn (Shenvi et al., 2013). However, no evidence has been found to support its value as a method of screening for CHD in the newborn. Boelke and Hokanson (2014) conducted a retrospective study of over 10,000 newborns. They found that the use of four limb blood pressure was unreliable in terms of both sensitivity and specificity for CCHD. Similarly, Shenvi et al., (2013) conducted a systematic review of the literature and found no evidence to support this procedure, due to the unacceptably high false positive rate. In addition, it is time consuming for the clinician and can cause unnecessary distress in the newborn. This lack of evidence suggests that this procedure should disappear from hospital guidelines.

By contrast, the use of pre and post ductal pulse oximetry when a murmur is heard in an asymptomatic newborn is supported by evidence. This test involves the measurement of oxygenated haemoglobin on either side of the ductus arteriosus. A pulse oximetry probe is placed sequentially around the newborn’s right hand (pre-ductal) and then either foot (post-ductal). The particular value of this test is that it can detect those forms of CCHD causing cyanosis, which may not be visible to the naked eye (Bruno and Havranek, 2015; Movahedian et al., 2015; ).

In recent years, there has been considerable interest in the addition of universal pulse oximetry screening for all newborns, not just those found to have a heart murmur. A growing body of evidence has shown that this can increase the sensitivity of newborn screening for the early detection of CCHD in the asymptomatic newborn (Valmari, 2007; Ewer et al., 2012; Thangaratinam et al., 2012;). The United States made pulse oximetry a universal requirement at the newborn examination in 2011, following a review of the evidence (Mahle et al., 2009; Kumar, 2016). Most recently a Cochrane Review on the subject has been published (Plana et al., 2018). The researchers reported a statistically significant increase in the sensitivity and specificity of the newborn screen for CCHD, when pulse oximetry testing was added. The overall sensitivity of pulse oximetry for detection of CCHD was 76.3% (95% confidence interval [CI] 69.5 to 82.0) and specificity was 99.9% (95% CI 99.7 to 99.9) (Plana et al.,2018).

In response to this emergent body of evidence, the UK NSC supported a pilot study in 2015. This was designed to establish the impact of routine newborn pulse oximetry screening in the NHS and was conducted across 15 hospital trusts in England (Evans, 2017). A recent announcement by the UK NSC in February 2019 stated that it was not in favour of offering pulse oximetry to all UK newborns. This was because, in their view, the benefits of screening would not outweigh the harms associated with the follow up of the screen positive babies. In the context of screening, the term harms includes issues such as increased parental anxiety, delay to discharge from hospital and admissions to the neonatal unit (Ewer, 2019). National public health screening decisions are complex and continue to be guided by the WHO criteria written by Wilson and Jungner (1968). The modified screening criteria adopted by the UK NSC includes the following clause:

*“The benefit gained by individuals from the screening programme should outweigh any harms, for example from overdiagnosis, overtreatment, false positives, false reassurance, uncertain findings and complications.”*

(UK NSC, 2017)

There has been some consternation on the UK NSC’s decision amongst experts in the field and children’s charities (Oddie et al, 2019; Children’s Heart Federation, 2019). In response, the UK NSC subsequently opened a public consultation on this issue, which closed recently in August 2019. It is hoped that the final decision on universal pulse oximetry screening will be made in early 2020.

### Conclusion

This article has reviewed the limitations of the newborn screen for congenital heart disease. It has been seen that at least 50% of cases of CHD will be undetected antenatally and that of those, up to 50% of cases will additionally be missed by the NPE. The aim at the NPE is to detect all significant forms of CHD, especially those forms that require urgent treatment. However, the midwife, nurse or doctor who follows a systematic approach, as set out by PHE, can only detect as many cases as are clinically possible at that time, given the complexities of the newborn’s physiology.

 Auscultation of an asymptomatic murmur at the NPE should trigger referral to a senior neonatologist, so that a clinically appropriate pathway can be followed. The measurement of four limb blood pressure is not supported by evidence as a useful screening tool for the asymptomatic newborn with heart murmur. However, performance of pulse oximetry should always be undertaken, as this will enhance the sensitivity and specificity for CCHD, when a murmur is present in the newborn.

The final decision from the NSC on universal pulse oximetry screening of the newborn is awaited with interest. Its inclusion as an adjunct to the NPE has been shown by a large body of research to increase the sensitivity of screening for cyanotic forms of CCHD that might otherwise go undetected.

**References**

 Bedford, C., & Lomax, A. (2015). Cardiovscular and respiratory assessment of the baby. In A. Lomax (Ed.), Examination of the newborn: An evidence based guide. (2nd Edition ed.). Chichester: John Wiley & sons.

Boelke, K., Hokanson, J. (2014). Blood pressure screening for critical congenital heart disease in neonates. Pediatric cardiology, 35, 1349-1355.

Bruno, C., Havranek, T. (2015). Screening for critical congenital heart disease in newborns. Advances in Pediatrics, 62, 211-226.

Children's Heart Federation (2019). Pulse Oximetry Campaign. Available from: <https://www.chfed.org.uk/campaigns/chf-pulse-oximetry-campaign/> [Accessed 28th September 2019].

Eckersley, L., Sadler, L., Parry, E., Finucaine, K., & Gentles, T. (2016). Timing of diagnosis affects mortality in critical congenital heart disease. Archives of Disease in Childhood, 101, 516-520.

Evans, C. (2017) Newborn pulse oximetry screening pilot update, PHE screening blog, 10th January. Available from: https://phescreening.blog.gov.uk/2017/01/10/newborn-pulse-oximetry-screening-pilot-update/#comments

Ewer, A., Furmston, A. T., Middleton, L., Deeks, J., Daniels, J., Pattison, H., et al. (2012). Pulse oximetry as a screening test for congenital heart defects in newborn infants: a test accuracy study with evaluation of acceptability and cost-effectiveness. Health Technology Assessment, 16(2), 1366-5278.

Ewer, A., (2014). Pulse oximetry screening for critical congenital heart defects in newborn infants: Should it be routine? Archives of Disease in Childhood - Fetal and Neonatal Edition, 99, F297-F302.

Ewer, A. (2019). Pulse oximetry screening - saving babies' lives. Available from: <https://www.birmingham.ac.uk/research/activity/metabolism-systems/Pulse-oximetry-screening-saving-babies-lives.aspx#nsc> [Accessed 28th September 2019].

Forsey, J., Elmasry, O., Martin, R. (2009). Patent arterial duct. Orphanet Journal of Rare Diseases. 4:17

Frommelt, M., Rademacher, R., & Kliegman, R. (2004). Differential diagnosis and approach to a heart murmur in term infants. The Pediatric Clinics of North America, 51(4), 1023-1032.

Gandhi, A., & Sreekantam, S. (2011). Evaluation of suspected congenital heart disease. Paediatrics and child health, 21(1), 7-12.

Hall, D., Elliman, D. (2003). Health for all children, revised fourth edition. Oxford, Oxford University Press.

Hoffman, L., & Kaplan, S. (2002). The incidence of congenital heart disease. Journal of the American College of Cardiology, 39, 1890-1900.

Kemper, A. (2011). Strategies for implementing screening for critical congenital heart disease. Pediatrics, 128(5), 1259-1267.

Knowles, R., & Hunter, R. (2014). Screening for congenital heart defects: External review against programme appraisal criteria for the UK NSC. University College London, UCL Institute of Child Health, London.

Kumar, P. (2016). Universal pulse oximetry screening for early detection of critical congenital heart disease. Clinical Medicine Insights: Pediatrics, 10, 35-41.

Mahle, W., Newberger, J., & Mathern, G. (2009). Role of pulse oximetry in examining newborn for CHD: A scientific statement from the Americal Heart Association and American Academy of Pediatrics. Circulation, (120), 447-458.

Mannarino, S., Codazzi, A., Diouf, A., Falcone, R., & Chiapedi, S. (2013). The neonatal heart murmur. Early Human Development, 8954, 537-538.

Mellander, M. (2013). Diagnosis and management of life-threatening cardiac malformations in the newborn. Seminars in Fetal & Neonatal Medicine, 18, 302-310.

Movahedian, A., Mosayebi, Z., Sgheb, S. (2015). Evaluation of pulse oximetry in the early detection of cyanotic congenital heart disease in newborns. The Journal of Tehran University Heart Center , 11 (2) 73-78.

Naik, R., & Shah, N. (2014). Teenage heart murmurs. Pediatric Clinics of North America, 61, 1-16.

NHS England. (2014). New congenital heart disease review: Recommendations to improve antenatal and neonatal detection of congenital heart disease (CHD). NHS England.

Oddie, S, Stenson, B, Wylie, J, Ewer, A (2019). UK consultation on pulse oximetry screening for critical congenital heart defects in newborns. The Lancet, 394 (10193), p. 103-104.

Patton, C., & Hey, E. (2006). How effectively can clinical examination pick up congenital heart defects at birth? Archives of Disease in Childhood: Fetal Neonatal Edition, 91, 263-7.

Peterson S. (2003). Congenital heart disease statistics. British Heart Foundation Health Promotion Research Group, Department of Public Health. Oxford: British Heart Foundation.

Plana, M., Zamora, J., Suresh, G., Fernandez-Pineda, L., Thangaratinam, S., & Ewer, A. (2018). Pulse oximetry screening for critical congenital heart defects. The Cochrane Library.

Powell, L (2019) Updated information on congenital heart disease published for parents, PHE screening blog, 30th January. Available from: <https://phescreening.blog.gov.uk/2019/01/30/updated-information-on-congenital-heart-disease-published-for-parents/> [Accessed 29th September 2019].

Public Health England. (2016). Newborn and infant physical screening programme handbook. London: PHE publications.

Shenvi, A., Kapur, J., & Rasiah, S. (2013). Management of asymptomatic murmurs in term neonates. Pediatric Cardiology, 34, 1438-1446.

Singh, A., Desai, T., Miller, P., & Rasiah, S. (2012). Benefits of predischarge echocardiography service for postnatal heart murmurs. Acta Paediatrica, 101, 333-336.

Singh, Y., Chee, Y., & Gahlaut, R. (2014). Evaluation of suspected congenital heart disease. Paediatrics and Child Health, 25(7), 7-12.

Thangaratinam, S., Brown, K., Zamora, J., Khan, K., & Ewer, A. (2012). Pulse oximetry: Screening for critical congenital defects in asymptomatic newborn babies: a systematic review and meta analysis. Lancet, 379(9835), 2459-2464.

Tucker Blackburn, S. (2018). Cardiovascular system. In S. Tucker Blackburn, Maternal, fetal and neonatal physiology (5th ed.). New York: Elsevier.

UK NSC [no date] UK National Screening Committee. Available from: <https://www.gov.uk/government/groups/uk-national-screening-committee-uk-nsc> [Accessed on 29th September 2019].

UK NSC (2017), UK NSC: Evidence Review Process. Available from: <https://www.gov.uk/government/publications/uk-nsc-evidence-review-process/uk-nsc-evidence-review-process> [Accessed 28th September 2019].

Valmari, P. (2007). Should pulse oximetry be used to screen for congenital heart disease? Archives of Disease in Childhood: Fetal and Neonatal Edition, 92(3), F219-F224.

Vargo, L. (2016). Cardiovascular assessment. In E. Tappero & M. Honeyfield, Physical assessment of the newborn (5th edition ed.). New York: Springer Publishing Company.

Wilson, J., & Jungner, G. (1968). Principles and practice of screening for disease. World Health Organisation. Geneva: World Health Organisation.

Wren, C., Reinhardt, Z., & Khawaja, K. (2008). Twenty year trends in diagnosis of life threatening neonatal cardiovascular malformations. Archives of Disease in Childhood: Fetal Neonatal Edition, 83, 414-419.