Pulse oximetry screening for critical congenital heart defects: a European consensus statement

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Critical congenital heart defects (CCHD), which require intervention in the first few weeks of life, occur in about two in 1000 livebirths and are an important cause of neonatal mortality and morbidity.[1–3] Surgical and catheter interventions now lead to excellent outcomes for most cases of CCHD, but timely detection is essential.[3] Existing screening strategies for newborn babies, including antenatal ultrasound and postnatal examination, do not detect CCHD before discharge in up to one-third of cases, and many of these infants will either collapse or die before diagnosis.[1–3]

Pulse oximetry screening (POS) improves early detection of CCHD in newborn babies by identifying those with low oxygen saturations.[1–7] POS has been shown to be simple, quick, painless,[1–3] and cost-effective and acceptable to both staff and parents.[3] Additionally, POS was shown to have a consistent test accuracy.[1–3] In the USA, POS for CCHD was added to the recommended uniform screening panel in 2011.[8] In Europe, POS is being used by an increasing number of hospitals, and pilot studies are underway in several countries.[9] However, to date, only a few countries (including Poland, Ireland, and Switzerland) have issued national guidelines recommending universal screening with pulse oximetry.[2]

POS is based on the concept, first described more than 20 years ago, that most babies with CCHD have lower oxygen saturations than healthy babies. However, the initial small studies[1–3] of POS were too imprecise to establish test accuracy. Between 2008 and 2014, several large, well designed studies[3–6] showed that POS was a highly specific, moderately sensitive test that met the criteria for universal screening. All studies[2,7] showed that addition of POS (with new-generation, motion-tolerant software) to existing screening methods (ie, antenatal ultrasound and postnatal examination) increased the overall detection of CCHD to 90–96%, irrespective of the detection rates of the other screening methods. Most studies[4,5,7,10] reported that important non-cardiac conditions, such as respiratory disorders, infections, and pulmonary hypertension, were also identified by POS, which might be an important benefit of this test.

Some heterogeneity exists in the screening algorithms used in the published studies,[4–7,10,11] including differences in the timing of initial screening, the use of single or dual sites for measuring oxygen saturation (post-ductal only or pre-ductal and post-ductal), and the cutoff values of oxygen saturation for a positive test.

Early screening (ie, within 24 h of birth) has been associated with a higher rate of false positives than screening after 24 h.[2,7,11] However, up to 50% of babies with CCHD might present with symptoms (including cardiovascular collapse) before 24 h of age; the same might be true for non-cardiac conditions identified by POS.[2] Additionally, many countries discharge a mother and her baby from hospital before 24 h, making later screening impracticable.[2]

When comparing different screening algorithms, consideration of sensitivity, specificity, and rates of false positives and false negatives is important. Screening should result in a timely diagnosis—ie, before presentation with acute collapse.[11] Most studies of POS have reported high specificities (>99%) and low false-positive rates (<1%),[7] meaning that most healthy babies will test negative. However, when considering national screening programmes, a high rate of false positives might affect a considerable number of babies,[7,11] requiring careful consideration to achieve a balance, both in clinical and economic terms, between test sensitivity and rates of false positives. Detection of non-cardiac diagnoses makes the issue of false positives more complex, although identification of these conditions is generally seen by clinicians as a potential advantage of POS.[10,11]

For a screening test to work in practice, it must be acceptable to the group agreeing to the screening (ie, the parents) and to the clinic staff who have to do the test and manage the consequences of the result. The large numbers of babies recruited into studies suggest POS is acceptable, but a formal assessment of acceptability was done as part of the UK PulseOx study.[3,5] In addition to assessing acceptability, the study assessed anxiety created by the test, particularly in mothers of babies with false-positive results.[3] However, most mothers were satisfied with screening, and anxiety was not significantly different between mothers of false-positive babies and those of true-negative babies.[3] Staff perceptions of testing were also assessed by focus groups and questionnaires, and POS was widely regarded as worthwhile and effective across all staff groups.[3]

See Online for appendix

Panel: **Recommendations from The European Pulse Oximetry Screening Workgroup**

- Pulse oximetry screening (POS) for critical congenital heart defects should be recommended for all European countries
- POS should be done with new-generation equipment that is motion tolerant
- Screening should occur after 6 h of life or before discharge from the birthing centre (preferably within 24 h after birth)
- Screening should be done in two extremities: the right hand and either foot
- Each country should consider the advantages and disadvantages of the two available protocols[4,5] and use that which best suits their population

Almost all the previous studies have screened babies in postnatal wards in a hospital setting.[1] However, in a home birth, the midwife usually leaves the mother and baby after 2 h, meaning that screening would either have to be done very early or delayed until the following day. Studies have shown that screening at 2 h after a home birth is feasible and that the test positive rate, although slightly higher than when screening is done later, is clinically acceptable.[1]

The situation in the neonatal intensive care unit (NICU) is different; babies are usually admitted because they are unwell or premature, which might affect oxygen saturation. Additionally, babies in the NICU usually undergo continuous pulse oximetry monitoring. Most published studies of POS have excluded babies admitted to the NICU for these reasons; however, if national screening programmes are to include all babies, then consideration of whom, how, and when to screen is important. The best approach has yet to be determined.

In all published studies, babies who tested positive with POS had a diagnostic echocardiogram to identify any congenital heart defects and to define test accuracy. This approach has led to the assumption that, during routine screening, all babies who test positive need an urgent echocardiogram. This assumption is not unreasonable because the consequences of missing CCHD are potentially severe. However, it is clear that most babies with false-positive results have a non-cardiac condition leading to test positivity (ie, a secondary condition that requires medical attention and prompt management).[10,11] Because a substantial proportion of babies with false-positive results have a respiratory problem or infection, the correct diagnosis might often be made after blood tests or radiographs and before echocardiography. Thus, echocardiography might only be used for babies in whom the diagnosis is unclear.[10,11]

To implement strategies to address these issues, neonatologists, experts in CCHD screening, and representatives from major scientific paediatric societies across Europe came together to create this recommendation (panel; appendix). We have tried to create common, shared, flexible, and evidence-based recommendations for use and standardisation of POS for early detection of CCHD across Europe. These recommendations should be considered at a national level as an approach to better identify CCHD, and other life-threatening conditions, in newborn babies.

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1 Narayen IC, Blom NA, Ewer AK, Vento M, Manzoni P, te Pas AB. Aspects of pulse oximetry screening for critical congenital heart defects: when, how and why. *Arch Dis Child Fetal Neonatal Ed* 2016; **101:** F162–67.
2 Ewer AK. Pulse oximetry screening for critical congenital heart defects. Should it be routine? *Arch Dis Child Fetal Neonatal Ed* 2014; **99:** F93–95.
3 Ewer AK, Furmston AT, Middleton LJ, et al. 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 Technol Assess* 2012; **16:** 1–184.
4 de Wahl Granelli A, Wennergren M, Sandberg K, et al. Impact of pulse oximetry screening on detection of duct dependent congenital heart disease: a Swedish prospective screening study in 39 821 newborns. *BMJ* 2009; **338:** A3037.
5 Ewer AK, Middleton LJ, Furmston AT, et al, for the PulseOx Study Group. Pulse oximetry screening for congenital heart defects in newborn infants (PulseOx): a test accuracy study. *Lancet* 2011; **378:** 785–94.
6 Zhao QM, Ma XJ, Ge XL, et al, for the Neonatal Congenital Heart Disease screening group. Pulse oximetry with clinical assessment to screen for congenital heart disease in neonates in China: a prospective study. *Lancet* 2014; **384:** 747–54.

7 Thangaratinam S, Brown K, Zamora J, Khan KS, Ewer AK. Pulse oximetry screening for critical congenital heart defects in asymptomatic newborn babies: a systematic review and meta-analysis. *Lancet* 2012; **379:** 2459–64.

8 Mahle WT, Martin GR, Beekman RH III, et al. Endorsement of Health and Human Services recommendation for pulse oximetry screening for critical congenital heart disease. *Pediatrics* 2012; **129:** 190–92.

9 Ewer AK, Granelli A, Manzoni P, Sánchez Luna M, Martin GR. Pulse oximetry screening for critical congenital heart defects. *Lancet* 2013; **382:** 856–57.

10 Singh AS, Rasiah SV, Ewer AK. The impact of routine pre-discharge pulse oximetry screening in a regional neonatal unit. *Arch Dis Child Fetal Neonatal Ed* 2014; **99:** F297–302.

11 Ewer AK, Martin GR. Newborn pulse oximetry screening: which algorithm is best? *Pediatrics* 2016; **138:** e20161206.