The scientific evidence for CCHD screening and its practical application using pulse oximetry.

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Critical Congenital Heart Defects (CCHD)

Critical CHD (CCHD) ~ 1-3/1000

May only be recognised when a baby develops life-threatening collapse.
Detection of CCHD by post-natal examination

- Granelli* (Sweden) Post natal exam

Cohort -108 604 (100 CCHD)

- CCHD discharged: 28/100 (28%)
- CCHD died: 5/100 (5%)
- CCHD collapse: 45/100 (45%)

Antenatal screening

- Anomaly scan detection rates are very variable between different countries and also within countries
Proportion of CHD requiring intervention for within 1 year of life identified antenatally in UK

% successfully diagnosed antenatally

Financial year

2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013

0%
10%
20%
30%
40%
50%

nicor.org.uk
<table>
<thead>
<tr>
<th>Country</th>
<th>2013/14</th>
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<tbody>
<tr>
<td>England</td>
<td>46.9%</td>
</tr>
<tr>
<td>Ireland</td>
<td>38.1%</td>
</tr>
<tr>
<td>N Ireland</td>
<td>38.6%</td>
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<tr>
<td>Scotland</td>
<td>37.6%</td>
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<tr>
<td>Wales</td>
<td>54.7%</td>
</tr>
<tr>
<td>GB and Ireland (overall)</td>
<td>45.7%</td>
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</table>
Babies with CCHD are frequently missed

...particularly when antenatal detection rates are low
Pulse oximetry screening

Rationale

Hypoxaemia (low saturations) present in the majority of critical CHD (CCHD)

Frequently clinically undetectable

Pulse oximetry may detect babies with CCHD early, before they collapse
• 8 studies - 35 960 patients
• Small numbers of patients, low prevalence of CCHD, methodological variations
• More high quality studies (in larger study populations) needed to precisely define test accuracy
Pulse oximetry studies 2009 - 2012

Early screening for critical congenital heart defects in asymptomatic newborns in Mazovia province: experience of the POLKARD pulse oximetry programme 2006–2008 in Poland

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Abstract
Background: Early diagnosis of critical congenital heart defects (CHD) may be missed during prenatal echocardiography and the first 24 hours of life. The aim of the POLKARD study was to evaluate the effectiveness of pulse oximetry screening in newborns and the need for additional postnatal examination.

Methods: A prospective screening pulse oximetry test was conducted in 10 neonatal units in the Mazovian province of Poland as part of the POLKARD (Pulse oximetry characterisation of newborns) programme between 1st January 2006 and 31st December 2008. The screening examined 20000 newborns. A double prenatal echocardiography (DPE) was performed in 9% of newborns, and a reverse test was performed in 76% of newborns that were not initially screened.

Results: A total of 55 cases of critical CHD were found. In 14% of cases, critical CHD was diagnosed before discharge and in 86% after discharge. In 40 cases, the diagnosis was made within the first month of life. The most common critical CHD was coarctation of the aorta (16 cases), followed by transposition of the great arteries (9 cases) and hypoplastic left heart syndrome (7 cases).

Conclusion: Early screening for critical CHD using pulse oximetry is effective and should be implemented in newborns at risk of developing critical congenital heart defects.

Key words: congenital heart defects, pulse oximetry, screening, polyvalent screening, infants.
Pulse oximetry studies 2009 - 2012

- Granelli – Sweden, (BMJ 2009)  [>24 hrs, Pre/post ductal]
- Riede – Germany, (EJP 2010)  [>24 hrs, Post ductal only]
- Ewer – UK, (Lancet 2011)  [<24 hrs, Pre/post ductal]
- Turska–Kmieć – Poland, (Kardiologia Polska 2012)  [<24 hrs, Post ductal only]
Detection of significant non-cardiac disease an important additional finding in all studies

(28-70% of false positives)

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Added value</th>
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<tbody>
<tr>
<td>Granelli</td>
<td>62%</td>
<td>99.8%</td>
<td>92%</td>
</tr>
<tr>
<td>Riede</td>
<td>77.8%</td>
<td>99.9%</td>
<td>95.6%</td>
</tr>
<tr>
<td>Ewer</td>
<td>75%</td>
<td>99.2%</td>
<td>92%</td>
</tr>
<tr>
<td>Turska–Kmieć</td>
<td>78.9%</td>
<td>99.9%</td>
<td>95%</td>
</tr>
</tbody>
</table>
Further work

Pulse oximetry screening

- Is acceptable to parents and staff
- Anxiety not increased in false positives
- Is cost-effective in an NHS setting
Pulse oximetry screening for critical congenital heart defects in asymptomatic newborn babies: a systematic review and meta-analysis

Shakila Thangaratnam, Kiritrea Brown, Javier Zamora, Khalid S Khan, Andrew KE Ewer

13 studies  229 421 patients (c.f. 8 studies, 36 000 pts)

Overall sensitivity 76.5% (95% CI 67.7% - 83.5%)
Overall specificity 99.9% (99.7% -99.9%)
False positive rate 0.14% (0.06 - 0.33)
(FPR <24 hrs 0.5%. FPR >24 hrs 0.05%)  
(Did not include full Polish study)
A new milestone in the history of congenital heart disease

...surely the question now is not ‘should pulse oximetry screening be introduced?’ but ‘why should such screening not be introduced more widely?’

Pulse oximetry with clinical assessment to screen for congenital heart disease in neonates in China: a prospective study

Qu-ming Zhao*, Xiao-jing Ma*, Xiao-ling Ge, Fang Liu, Wei-li Yan, Lin Wu, Ming Ye, Xue-cun Liang, Jing Zhang, Yan Gao, Bing Jia†, Guo-ying Huang†, and the Neonatal Congenital Heart Disease screening group†

• 120 707 babies screened
• Pre and post-ductal saturations
• Sensitivity for CCHD – 83.6%
• False positive rate 0.3%
'Further trials are unnecessary. Now is the time for professional bodies to review the evidence and consider a pulse oximetry screening protocol that best suits their requirements'

Limitations

• Not a perfect test, but better than existing

• Will miss approximately 20 - 25% of CCHD

• Commonest defects missed – CoA, IAA
  
  Ewer – 43% (3/7)
  Zhao – 42% (5/12)
  Turska–Kmieć – 33% (1/3)
  Granelli – 21% (3/14)
  Riede – 0% (0/2)

• Not a replacement for existing screening
Why not screen?

- Insufficient staff
- Concerns about false positives
- Impact on clinical services, particularly echocardiography

Singh and Ewer Lancet 2013;381:535
How should screening be done?
Screening protocols

• Pre and post or post-ductal only?

• Early or late screening? (<24 hrs or >24 hrs)
Pre and post-ductal vs Post-ductal

- No difference in sensitivity in meta-analysis
- Pre/post consistently identifies CCHD which would have been missed by post-ductal
  
  Granelli – 1 CCHD
  Ewer – 3 CCHDs

Equivalent to 7 CCHDs per 100 000 births
Early or late screening
(<24 or >24hrs)

• Most babies have ‘normal’ sats within 2 hr

• FP lower if PO screening >24 hr
  0.05 vs 0.5%
CCHD presenting before screening

- Later screening studies report 50% of CCHD babies presented before screening\textsuperscript{1,2}

Up to 10% present with collapse in hospital \textsuperscript{1}

1. Granelli BMJ 2009
2. Riede EJP 2010
CCHD presenting before screening

- New Jersey experience – 2011 -2012
  72,694 babies screened –
  FP rate 0.04% but only 3 CCHDs identified\(^1\)

- Not specified but likely many CCHDs presented before screening (70-140 CCHD expected)

The impact of routine predischarge pulse oximetry screening in a regional neonatal unit

Anju Singh,¹ Shree Vishna Rasiah,¹ Andrew K Ewer¹,²


• BWH screening programme
2010-2013 (40 months)
• Total Livebirths: 25 859
• Most babies screened <12 hrs (mean age 7 hrs)
• Test positive pulse oximetry: 208
  0.8% of all livebirths - Just >1 admission a week

Congenital heart defects identified: 17
  – Critical CHD: 9 [+2FNs]
  – Serious CHD: 3
  – Significant CHD: 5

55 pneumonia, 30 sepsis, 12 PPHN. Only 43 (21%) were healthy (True FPs)

Echocardiograms

- Echos performed for test +ve pulse Ox:
  
  61/208 (29%)

- Abnormal Echos: 29/61 (48%)
Murmurs and echocardiography

- 3 year data from Birmingham Women’s Hospital
- 205 echos for babies with murmur
- 123 (60%) no significant abnormality
- 72 (35%) septal defects
- 2 (1%) CCHD – 1 CCHD/100 scans
- [PulseOx 9/61 (15%) CCHD] – 1 CCHD/6.5 scans

False positives

Need to consider trade off between false positive rate and timely diagnosis

Also...
Earlier diagnosis of respiratory/infective cases
Increasing discharges within 24 hours

False positives are babies with low oxygen levels
No baby should have unexplained persistent hypoxaemia
Press release

UK National Screening Committee recommends new test for newborn babies with heart disease

From: Public Health England
History: Published 7 May 2014
Part of: Giving all children a healthy start in life.
Children and young people, National Health Service and Public health

The UK NSC wants to pilot pulse oximetry in England. It is a simple test that can screen babies for congenital heart defects.

Pulse oximetry is a simple test where a clip placed on a baby’s fingers and toes measures the amount of oxygen in their blood. Its use can help the NHS find many more babies with serious heart disease so they can be treated to prevent deaths and long term disability. The committee wants to use the pilot to better understand the implications of using the test on services for newborn babies.
Pulse oximetry pilot under way

The newborn pulse oximetry screening pilot has begun. The aim of the pilot is to:

- understand the impact of implementing newborn pulse oximetry screening on NHS services
- find out if it is feasible to rollout pulse oximetry nationally as an addition to the existing newborn and infant physical examination tests within 2 hours of birth

The pulse oximetry test screens for congenital heart disease by measuring oxygen levels in the blood.

Experts working with the pilot team include Professor Andy Ewer and Dr. Matt Cavanagh, who are based at the Birmingham Women’s Hospital. During March and April, the team completed stakeholder site visits to all 15 of the participating trusts.

The next phase of the pilot starts on 1 July when participating trusts will offer pulse oximetry screening to all eligible newborn babies using the nationally developed pathway. Pulse oximetry fields have been added to the NPIF SMART II system to accommodate this change. These fields are currently only available in the pilot sites and include local and national reporting functionality.

New pulse oximetry information resources used in the pilot sites include a leaflet and information flyer for parents and a flyer for health professionals.

The information flyers for parents will be distributed to antenatal clinics and midwife-led antenatal clinics in GP surgeries to give parents advance notice that the pilot is taking place in their trust.

The parent leaflet will be given at the 16 weeks’ gestation antenatal appointments and again at the time of the pulse oximetry screen if necessary. Online education and training was provided in May and June at the participating trusts.

In addition, a newly developed pulse oximetry screening film has been made available to the pilot sites. The NIPF team provided each of the participating trusts with a resource pack that included clinical guidance, information and training resources. The content of these packs will also be evaluated as part of the pilot.
UK pilot - Methods

15 acute Hospitals participated over 6 months
1st Jul 2015 – 31st Dec 2015

- rural MLU to tertiary centres (incl. homebirths)
UK Newborn Pulse Oximetry Screening Pilot Pathway
UK pilot

- 32,836 babies screened
- 239 test positives (0.73%)
- 14 CHD (8 CCHD) – [2 FNs]
- 82 significant non-cardiac disease
# PO screening vs. Hearing screening

## UK experience - screening well babies

<table>
<thead>
<tr>
<th></th>
<th>Hearing*</th>
<th>PulseOx(BWH)</th>
<th>PulseOx(UK)</th>
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<tbody>
<tr>
<td>Referral rate</td>
<td>2.2%</td>
<td>0.8%</td>
<td>0.73%</td>
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<tr>
<td>Target condition pick-up**</td>
<td>7</td>
<td>3.4</td>
<td>2.4</td>
</tr>
<tr>
<td>False positives†</td>
<td>213</td>
<td>80</td>
<td>70</td>
</tr>
</tbody>
</table>

**Per 10 000 tests**

*(60 w/ sig. illness) (25 w/ sig. illness)*

Summary

• Pulse oximetry screening is feasible, acceptable, cost-effective and reduces the diagnostic gap for CCHD.

• Most appropriate algorithm is likely to be refined with national input from national datasets and may be adjusted according to local circumstances.
Reviews and commentaries


• Ewer AK. Pulse oximetry screening for critical congenital heart defects. Should it be routine? *Arch Dis Child Fetal and Neonatal Ed* 2014;99:F93-F95.


• Ewer AK, Martin GR. Newborn pulse oximetry screening: which algorithm is best? *Pediatrics* 2016 (in press).

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