Dr Michelle Heys, PI NeoTree  
Associate Professor UCL, UK and  
Consultant Paediatrician and joint Associate  
Clinical Director, East London NHS  
Foundation Trust, UK  
27th Feb 2020  

On behalf of: the wider NeoTree team  

On behalf of: the NeoTree team
The Problem

2.9 million neonatal deaths globally

Lack of hospital data systems

Poor quality neonatal care

↓ 70%

through implementation of existing evidence-based guidelines
Our aims | NeoTree

- Improve newborn care
- Reduce newborn mortality
What is the NeoTree?

A digital Health system aiming to improve newborn survival in low resource hospitals

For newborn health care workers (HCWs) of all cadres

To admit & discharge newborns using digital forms on a tablet based application

…the digital forms have inbuilt decision support & education according to evidence based guidelines (WHO, COIN etc.)
The NeoTree

1. Immediate data capture
2. Clinical decision support
3. Education
4. Data transfer – local and national
5. Data-driven quality improvement

1. Data capture
2. Decision support (emergency /diagnostic)
3. Education
4. Data transfer
5. Data-driven quality improvement
## Our Ethos

<table>
<thead>
<tr>
<th>Open-source code</th>
<th>Country data ownership</th>
<th>High end software</th>
<th>Low cost hardware</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-production (micro/ meso / macro)</td>
<td>Participatory</td>
<td>Not for profit</td>
<td>Data driven quality improvement</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Responsive, adaptable</td>
<td>Empowerment of HCW</td>
<td>Compatible</td>
</tr>
</tbody>
</table>

**Innovation for immediate impact**
**Timeline**

**Phase 1**
- Literature review & NeoTree Concept development
- Identification and exploration of potential NeoTree sites (Nepal/Bangladesh)
- Pre-development screens, early prototype & simple exemplar algorithm
- Theoretical usability, acceptability workshop & health facilities audit, Bangladesh

**Phase 2**
- Development of NeoTree-alpha (UK) - including coding of Editor platform
- Configuration of admission form to match Malawian national admission form

**Phase 3**
- Qualitative study of barriers and facilitators to improving newborn care
- Iterative user-centric co-development of NeoTree-Beta, Zomba Central Hospital, Malawi
- Pilot testing, usability, acceptability and feasibility
- Configuration of NeoTree clinical algorithms, management support & education

**Phase 4**
- QI intervention evaluation NeoTree for sepsis, Harare Central Hospital, Zimbabwe
  (development of NeoLab and extended NeoDischarge)
- Global expert review of clinical algorithm (sepsis/HIE/thermoregulation/resp distress)
- Further conceptualization of data linkage with national aggregate systems/EMR
- Co-development of data dashboard prototype and ongoing evaluation of NeoTree-Beta using Behaviour change theory, Kamuzu Central Hospital, Malawi

**Phase 5**
- Clinical validation study of diagnostic algorithm
- NeoTree –gamma co-development and testing ready for evaluated roll out

---

**Software development cycle**

- Prototype
- Alpha: development releases
- nightly builds
- Beta
- Release Candidate
  (gamma delta)
Phase 1
(2014-16)
- Literature review – barriers to reducing newborn mortality & potential solutions
- NeoTree Concept development
  - Identification of potential NeoTree sites
  - Baseline audit of health facilities Bangladesh
  - Early pre-development screens

**NeoTree-Protype and concept refinement**

**Digital health could be part of the solution**
Review of available literature

Potential causes for stagnation of NMR decline
- Disparities in access to skilled attendance at birth and adequate postnatal newborn care
- Shift to institutional deliveries
- Quality of institutional care

Barriers to the scale up of institutional neonatal care
- Lack of specialized neonatal care training
- Lack of communication and coordination between providers
- Lack of evidence-based interventions for providers to postnatal care for vulnerable newborns

Elements of the NCN
- Newborn Health Education
- mHealth "NEO-Tree" app
- vNET

Arrows demonstrate the elements of the NCN addressing each identified barrier

SOLUTION?
Newborn care network
**UID of baby**

**Date/Time of Birth**

**Birth Weight (kg)**

**Gestational Age (wks)**

**Admitted from**

**Place of birth**

I need help with neonatal resuscitation now. Click the red button.

Method of estimation drop-down
1) Fundal height
2) LMP
3) USS – date:
4) Ballard Score:

Link to Ballard /maturity score

Drop-down
a) LW/PNW
b) Theatre
c) OPD
d) Under 5
e) Referred from outside:
   - Home (self referral)
   - Other HC/Hospital:

If BW < 2.5kg add low birth weight to problem list

If <37 wks add risk of sepsis to problem list

If born at home or BBA add risk of sepsis to problem list

Link to useful terms
Back to home screen
Information
Phase 2
(2016)
• Prototype adapted and developed using Ninjamock and data entry for admission form configured to match Malawian MoH form
• Coding of NeoTree-alpha (UK)
• Includes coding of Editor platform and android app
  - Configuration of form with integrated clinical management
  - Creation of new logo
  - Created a website and introductory video
<table>
<thead>
<tr>
<th>Title</th>
<th>Description</th>
<th>Screen Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neotree</td>
<td>Alpha version</td>
<td>Checklist</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pos</th>
<th>Title</th>
<th>Name</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Welcome to The NeoTree</td>
<td>Checklist</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>NavW/NA NeoNav1</td>
<td>New Assessment</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>NA UID</td>
<td>New Assessment</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>ET1 Baby crying</td>
<td>Emergency Triage</td>
</tr>
</tbody>
</table>
Phase 3
(2016-17)

- Configuration of NeoTree-Beta clinical algorithm according to international and Malawian guidelines (COIN: Care of the Infant Newborn)
- Pilot testing & intervention co-development of NeoTree-Beta, Zomba Central, Malawi
- Qualitative study of barriers and facilitators to delivery of quality newborn care
- Iterative user-centric coproduction and app development
- Configuring of simple NeoTree-discharge forms
- Media footage, film, website

NeoTree-Beta

Highly usable acceptable and feasible tool
NeoTree App Interface (Front End)

1. Data collection

2. Decision support (2a Emergencies)
   - Not Breathing
   - Abnormal
   - Breathing
   - Normal
   - Breathing
   - Normal
   - Breathing
   - Normal

3. Data transfer

3. Data collection

Decision support (2b non-emergency /diagnostic)

Decision support (2c management summaries)
The NeoTree application: developing an integrated mHealth solution to improve quality of newborn care and survival in a district hospital in Malawi

Caroline Crehan,1 Erin Kesler,1 Bejoy Nambari,2 Queen Dube,3 Norman Lufesi,4,5 Matteo Giaccone,6 Charles Normand,7 Kishwar Azad,8,9 Michelle Heys1

ABSTRACT
More than two-thirds of newborn lives could be saved worldwide if evidence-based interventions were successfully implemented. We developed the NeoTree application to improve quality of newborn care in resource-poor countries. The NeoTree is a fully integrated digital health intervention that combines immediate data capture, entered by healthcare workers (HCW) on admission, while simultaneously providing them with evidence-based clinical decision support and newborn care education. We conducted a mixed-methods intervention development study, co-developing and testing the NeoTree prototype with HCWs in a district hospital in Malawi. Focus groups explored the acceptability and feasibility of digital health solutions before and after implementation of the NeoTree in the clinical setting. One-to-one theoretical usability workshops and a 1-month clinical usability study informed iterative changes, gathered process and clinical data, System Usability Scale (SUS) and perceived improvements in quality of care. HCWs perceived the NeoTree to be acceptable and feasible. Mean SUS before and after the clinical usability study were high at 80.4 and 86.1, respectively (above average is >68). HCWs reported high...

Summary box
► More than two-thirds of newborn lives could be saved worldwide if evidence-based interventions were successfully implemented.
► Reliable data sources and health information systems for counting births, stillbirths, neonatal deaths and delineating the causes of death are lacking.
► With the fast-moving digital revolution in low-income countries mobile health applications are being increasingly designed but these have not yet focused on facility-based newborn care.
► Here we present the NeoTree application, focusing on newborn care in low-income facilities, combining data collection by healthcare workers themselves, with interactive decision support and education for improving quality of care.
► We report iterative codevelopment with healthcare workers to create a highly usable interactive admission platform, which provides teaching and training, improving the perceived quality of care delivered by healthcare workers while admitting the baby.

Highly usable, feasible and acceptable tool
Implementation recommendations
Phase 4  
(2018-19)

- International expert review of clinical algorithm (sepsis/ HIE/ thermoregulation/ respiratory distress)
- Quality improvement project: NeoTree to address sepsis management, Harare Central Hospital, Zimbabwe
- Configuration of NeoTree-Lab and extended NeoTree-discharge pages
- Development of data dashboard using Behaviour change theory and frameworks, Kamuzu Central Hospital, Malawi
- Development of monthly data dashboard using R code based, HCH, Zimbabwe
- Further conceptualization of data linkage with Zimbabwe aggregate data system working with Zimbabwean Ministry of Health

NeoTree-Beta
Key functions
1. Data capture
2. Decision support
3. Education
4. Data linkage
PRELIMINARY KEY MESSAGES FROM PHASE 4 IMPLEMENTATION

Harare Central Hospital, Zimbabwe:
1. Continuity of care despite doctors strikes – nurses now using the digital platform
2. Instant data capture and feedback for clinicians and management
3. Linkage with lab data
4. Improved antimicrobial stewardship on discharge

Kamuzu Central Hospital, Malawi:
1. Successful implementation and sustained use in a busy unit
2. Sustained high usability
3. Data driven change in quality of care – especially around thermoregulation of babies
4. Impact on mortality & morbidity meetings with obstetrics and gynaecology
Dashboard prototypes have been developed to give 3 outputs – these update in real time:

1. Mortality & Morbidity slide deck
2. Summary statistics dashboard
3. Behaviour change dashboard
Phase 5
(2019-21 – Wellcome trust funded)

- Ongoing implementation in HCH and KCH
- Additional implementation in Chinhoye provincial hospital, Zimbabwe
- Revision of diagnostic algorithms according to expert review and modelling
- Clinical validation of key diagnostic algorithms (sepsis/ HIE/ resp distress)
- Staged implementation evaluation of full functionality of NeoTree-Gamma
- Protocol for robust evaluation at scale, including health economic analysis
- Development of data linkage to national data systems (DHIS-v2)

NeoTree-Gamma
Ready for large scale evaluated roll out
Some educational elements included in NeoTree Plan for augmented educational programme (subject to funding)

NeoTree Gamma by 2021

NeoCloud data linkage locally and nationally under development; other components conceptualised only
#MADEATUCL & PARLIAMENTARY REVIEW

- Top 100 innovations across UCL
Our vision

NeoTree Neonatal international consortium

NeoTree should be at every newborns bedside

Counting every newborn

Caring for every newborn

www.neotree.org  #the_neotree  neotreeapp@gmail.com  @the_neotree
ACKNOWLEDGEMENTS

PRINCIPAL INVESTIGATOR
· Dr Michelle Heys, Associate Professor Great Ormond Street Institute of Child Health (GOS-ICH), University College London (UCL), UK and Consultant Paediatrician, East London NHS Foundation Trust, UK

IN-COUNTRY PRINCIPAL INVESTIGATORS
· Dr Simbarashe Chimhuya, Paediatrician and clinical lead at Harare Central Hospital and lecturer at University of Zimbabwe.
· Dr. Msandeni Chiume-Kayuni, head Paediatric Consultant at Kamuzu Central Hospital, Lilongwe, Malawi

CO-INVESTIGATORS
· Miss Erin Kesler, Children’s Hospital of Philadelphia, USA
· Dr Caroline Crehan, GOS-ICH UCL, UK
· Dr Felicity Fitzgerald, GOS-ICH, UCL
· Mr. Tim Hull-Bailey, GOSH-ICH, UCL
· Dr Hassan Haghparrast-Bidgoli, Institute for Global Health (IGH), UCL
· Prof Monica Lakhpanaul, GOSH-ICH, UCL
· Dr Fabiana Lorencatto, Centre for Behaviour Change, UCL
· Dr Hannah Gannon
· Prof Mario Cortina Borja, GOS-ICH, UCL
· Dr Gwen Chimhini
· Dr Emma Wilson, GOS-ICH, UCL
· Dr Liam Shaw, Modernising Medical Microbiology, University of Oxford.

SOFTWARE DEVELOPMENT TEAM
· Mr Yali Sassoon
· Mr Charles Normand
· Mr Louis du Toit

RESEARCH PARTNERS/ COLLABORATORS
· Dr Bejoy Nambiar, UNICEF, Malawi
· Dr Norman Lufesi, Acute Respiratory Illness department, Ministry of Health (MoH), Malawi
· Dr Queen Dube, Head Paediatric Consultant at Queen Elizabeth Central Hospital (QECH), Blantyre
· Prof Valerie Robertson, University of Zimbabwe
· Dr Shungu Munyati is Director-General of the Biomedical Research and Training Institute (BRTI), Zimbabwe
· Dr Robert Gongora, Ministry of Health (MoH), Zimbabwe
· Dr Gregory Valentine. Clinical Neonatal Fellow at Baylor Institute of Medicine and Texas Children’s Hospital
· Dr Pascal Lavoie. Neonatologist at British Columbia Women’s Hospital and Associate Professor, University of British Columbia
· Dr Simbini

CURRENT/ PREVIOUS RESEARCH STUDENTS
· Mr Sam Neal, UCL
· Dr Mari Evans (UCL, MSc 2019)
· Miss Erin Kesler (UCL, MSc 2014)

TECHNICAL ADVISORY BOARD
· Dr Tim Colbourne, IGH, UCL
· Dr Logan Manikam, GOS-ICH, UCL
· Dr Ed Fottrell, IGH, UCL
· Mr Marcus Wooton, Royal College of Paediatrics and Child Health (RCPCH), UK
· Dr Alex Stevenson, Neonatologist, Zimbabwe

AND ALSO
· Prof Anthony Costello, UCL
· Mr Matteo Giaccone (software development)
· Dr Patty Costcova, UCL
· Dr Rizine Mzikamanda, Malawi
· Miss Lauren Kesler
· Miss Brittany Abernathy
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Slide acknowledgements: Caroline Crehan, Tim Hull-Bailey, Erin Kesler, Simba Chimhuya, Hannah Gannon

Special thanks to all the doctors, nurses, babies and families for their time, enthusiasm and participation in the NeoTree journey
SPARES
MANAGEMENT PAGES AT THE END OF ADMISSION

1. Assess extent of jaundice

   - If the jaundice is limited to area 1, then the serum bilirubin is likely in the range 150-200 mmol/L. Only start phototherapy if day 1.
   - If the jaundice involves area 1-2 i.e. over the trunk, then the serum bilirubin is likely in the range 200-350 mmol/L. If premature, use birth weight, or term but sick and there is jaundice over the trunk start phototherapy.
   - If the jaundice extends to include the ears (1-2) and nose, mouse the nose and ears than serum bilirubin is likely 350-500 mmol/L.
   - Start phototherapy on all babies including early term babies if the jaundice extends to include the palms and soles.

2. Start phototherapy if necessary
   - Protect the baby’s eyes with a mask
   - Watch for dehydration
   - Mothers can still breast feed

3. Further management:

   Clinician to assess potential etiology:
   - LBW
   - Asphyxia
   - Prematurity
   - ABO incompatibility
   - Birth trauma
DISCHARGE FORM – DATA COLLECTION

Number of days of CPAP?
<table>
<thead>
<tr>
<th>Year</th>
<th>NeoTree version</th>
<th>emergency diagnostic algorithms</th>
<th>management guidelines</th>
<th>non-emergency diagnostic algorithms</th>
<th>emergency management</th>
<th>clinical validity data</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-2014</td>
<td>Concept</td>
<td>✅</td>
<td>✗</td>
<td>✗</td>
<td>Bangladeshi HCW</td>
<td>✅ (partially)</td>
</tr>
<tr>
<td>2014-2015</td>
<td>Prototype</td>
<td>✅</td>
<td>simple hypotheria</td>
<td>✗</td>
<td>Bangladeshi HCW</td>
<td>✅ (partially)</td>
</tr>
<tr>
<td>2016</td>
<td>NeoTree alpha</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>Malawian HCW</td>
<td>✅</td>
</tr>
<tr>
<td>2018-2019</td>
<td>NeoTree-Beta</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>Zimbabwean HCWs</td>
<td>✅</td>
</tr>
<tr>
<td>2019</td>
<td>NeoTree-Beta</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>Malawian HCW</td>
<td>✅</td>
</tr>
<tr>
<td>2018-2019</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2019-2020</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>NeoTree-Beta</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>Malawian/Zimbabwean HCW</td>
<td>✅</td>
</tr>
<tr>
<td>2020-2021</td>
<td>NeoTree-Gamma</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>Malawian/Zimbabwean HCW</td>
<td>✅</td>
</tr>
</tbody>
</table>

OVERVIEW OF ALGORITHM DEVELOPMENT

- **emergency diagnostic algorithms** conceptualised and developed according to international guidelines and available evidence
- **management guidelines** configured and refined according to international and national guidelines, available evidence and clinical judgement
- **lab data (blood cultures) linked to clinical data; discharge data augmented**

International Delphi consensus study and review of diagnostic algorithms (sepsis/HIE/respiratory distress and hypothermia)

Ethnographic study of adherence to emergency guidelines

Analysis of validity data and revision of algorithm

Literature review of HIC/LMIC sepsis algorithms and modelling of sepsis data
limited evidence on HCW led facility-based postnatal interventions to decrease mortality in LBW infants.
- lack of consistent scale-up.
- Packages of care needed
- Implementation
- sustainability.
# Diagnoses potentially generated by NeoTree algorithm

<table>
<thead>
<tr>
<th>Categories / problems:</th>
<th>Symptoms / states:</th>
<th>Diagnoses:</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. VLBW</td>
<td>17. Risk of Hypoglycaemia</td>
<td>27. Consider birth asphyxia</td>
</tr>
<tr>
<td>3. ELBW</td>
<td></td>
<td>28. Birth asphyxia</td>
</tr>
<tr>
<td>4. Big Baby</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Premature</td>
<td>18. Mild hypothermia</td>
<td>29. EONS asymptomatic</td>
</tr>
<tr>
<td>7. Extremely premature</td>
<td>20. Severe hypothermia</td>
<td>31. EONS symptomatic</td>
</tr>
<tr>
<td></td>
<td>21. Hypothermia</td>
<td>32. LONS symptomatic</td>
</tr>
<tr>
<td>9. HIV exposed</td>
<td>23. Abdominal obstruction</td>
<td>34. Anaemia</td>
</tr>
<tr>
<td>12. Consider meningitis</td>
<td></td>
<td>37. ? Pneumocystis Jerovechei Pneumonia</td>
</tr>
<tr>
<td>13. Consider tetanus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Untreated maternal syphilis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Birth Trauma</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Respiratory distress of the newborn:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>38. TTN: Transient Tachypnoea Newborn</td>
</tr>
<tr>
<td></td>
<td></td>
<td>39. RDS: Respiratory distress Newborn</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40. MA: Meconium Aspiration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>41. CPN: Congenital Pneumonia</td>
</tr>
</tbody>
</table>

**Notes:**
- TTN: Transient Tachypnoea Newborn
- RDS: Respiratory distress Newborn
- MA: Meconium Aspiration
- CPN: Congenital Pneumonia
QUALITATIVE STUDY: HCW PERCEIVED BARRIERS AND FACILITATORS TO DELIVERY OF QUALITY CARE (MANUSCRIPT IN PREPARATION)

Figure 1. Perceived Barriers to quality of newborn care – Themes from focus groups with facility Health Care Workers
QUALITATIVE STUDY: HCW PERCEIVED BARRIERS AND FACILITATORS TO DELIVERY OF QUALITY CARE (MANUSCRIPT SUBMITTED)

Figure 2: Perceived facilitators to quality of newborn care – Themes from focus groups with facility Health Care Workers
A DIGITAL PERINATAL OUTCOME AUDIT OF ADMISSIONS TO A DISTRICT HOSPITAL NEONATAL UNIT IN MALAWI USING THE NEOTREE APPLICATION (MANUSCRIPT SUBMITTED)

Table 2. Case fatality rate

<table>
<thead>
<tr>
<th>Primary diagnosis*</th>
<th>Number of infants (n)</th>
<th>Number of deaths (n (%))</th>
<th>Case fatality rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prematurity with RDS</td>
<td>7</td>
<td>3 (42.8)</td>
<td>428/1000 cases</td>
</tr>
<tr>
<td>Birth Asphyxia</td>
<td>30</td>
<td>7 (23.3)</td>
<td>233/1000 cases</td>
</tr>
<tr>
<td>Neonatal sepsis</td>
<td>44</td>
<td>1 (2.3)</td>
<td>23/1000 cases</td>
</tr>
<tr>
<td>Congenital Anomaly</td>
<td>6</td>
<td>1 (16.7)</td>
<td>167/1000 cases</td>
</tr>
<tr>
<td>Other</td>
<td>42</td>
<td>0 (0.0)</td>
<td>0/1000 cases</td>
</tr>
<tr>
<td>Total admissions</td>
<td>129</td>
<td>12 (9.3)</td>
<td>93/1000 admissions</td>
</tr>
</tbody>
</table>

RDS = Respiratory Distress Syndrome. *Primary diagnosis was the most salient diagnosis (cause of death for neonatal deaths), decided by the researcher by reading the medical record and using clinical judgement as a neonatal registrar. These are mutually exclusive. Primary, secondary and tertiary diagnoses were recorded where necessary.
EXPERT REVIEW OF CLINICAL CONTENT AND VALIDATION OF CLINICAL ALGORITHM (MANUSCRIPT IN PREPARATION)

• Round 1: n=14 experts, n=9 (HIC); n=5 LIC

• Round 2: 10 experts

• Consensus reached on 52% of items

• Items must be consistent with local and WHO guidelines

• Example of key changes
  • HIE should use Thompson scoring system
  • Sepsis algorithm shouldn’t use weighted system for diagnosis, but more evidence should be gathered (HCH, MRes study)
  • the revised respiratory algorithm, all neonates with respiratory distress will be given antibiotics
WHO HAS USED THE NEOTREE IN KCH?

Who is using NeoTree?
• 90 different HCWs
• 5 different cadres (TBC)

How many times?
Permanent staff: Average 90 times (Range 23-195 times)
All users: Average 13 times (Range 1-195 times)

How long did it take?
7 mins - >1hr (difficult to measure)
Median time taken Sep/Oct - 25 mins
Most people take < 20 mins
Discharge only takes 10 mins
**STANDARD:** Midwives & neonatal nurses must keep all newborns warm (> 36.5 °C) at all times, particularly after birth & in transit to nursery so that all admission temperatures are >36.5°C

**>70% Hypothermia on admission at EMN!**

<table>
<thead>
<tr>
<th>Admission temperature, Ethel nursery, August 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>80%</td>
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<tr>
<td>70%</td>
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<tr>
<td>60%</td>
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<tr>
<td>50%</td>
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<tr>
<td>40%</td>
</tr>
<tr>
<td>30%</td>
</tr>
<tr>
<td>20%</td>
</tr>
<tr>
<td>10%</td>
</tr>
<tr>
<td>0%</td>
</tr>
</tbody>
</table>

- Hypothermia 72%
- Normothermia 20%
- Hyperthermia 8%

**GOAL:** Reduce admission hypothermia to below 50% by next month!

**How can we improve?**

- **Midwives in theatre, LW, Gynae or PNW must:**
  - **DRY** thoroughly with a warm towel **AT THE SCENE!**
  - **WRAP** with a 2nd warm towel **AT THE SCENE!**
  - **RESUSCITATE** if necessary **AT THE SCENE!**
  - **MOVE** quickly to nursery, when stable, keeping warm

- **Neonatal nurses in the nursery must make sure:**
  - **DOORS** are closed
  - **WINDOWS** closed
  - **CHECK EQUIPMENT**-warmer/incubator is ON & working!
  - **MONITOR** temperature regularly **UNTIL** baby normothermic
QI DATA PROJECTS (2019-2020)

Zimbabwe
• AN steroid exposure and neonatal outcome
• Outcome at discharge for babies with hypoxic ischaemic encephalopathy
• Outcome at discharge for babies with sepsis

Malawi
• Outcome at discharge for babies with gastroschisis
• Monitoring of vital signs
• Thermo regulation
ON ADMISSION

Quality improvement through educational / training pictures

In emergency management & triage
NEXT STEPS

- “Mummy Tree”
- Daily EMR
- NeoTree charity
- Link with community groups / data
  - Especially for high risk newborns – eg post HIE
- Development of the app functionality for other groups eg AN maternal care and paediatric sepsis - QECH
Phase 5
(2019-21 subject to funding decision)

- Ethnographic evaluation of adherence to emergency diagnostic algorithm
- Development of educational arm
- Implementation in Queen Elizabeth Blantyre, Malawi

NeoTree-Gamma+
ZIMBABWE HARARE CENTRAL HOSPITAL

• 12,000 births per year,
• 4,800 admissions
• <4% blood test results returned in time to affect care of the newborn
• 97% babies discharged on oral antibiotics

Goals
1. To improve adherence to best practice guidelines for junior doctors and so improve care
2. To standardise and improve data collection for ease of audit and monitor unit activity
3. To reduce turn around time for blood culture results from median 6 days
4. And so improve management of sepsis and infection control
MDRes study Dr Crehan

Implementation introduced over 4 week period

Data collection since 24\textsuperscript{th} April:-

• 1436 admissions
• 1238 matched discharges/deaths
• (Outcome data available for 86%)

> 90 different HCWs & 5 different cadres have used the app

High usability (SUS score 88.3; core > 65 is considered above average)

Acceptability and feasibility according to behaviour change data awaiting analysis

• Rates of admission hypothermia are improving (down from 72% to 68%)

Co-development of data-dashboard prototype