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ORIGINAL ARTICLE

Clinical outcomes and cost-effectiveness of large-scale midwifery-led, paediatrician-overseen home phototherapy and neonatal jaundice surveillance: A retrospective cohort study

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Aim: To evaluate a large midwifery-led, paediatrician-overseen home jaundice surveillance and home phototherapy (HPT) programme.

Methods: We conducted a retrospective cohort study over 2019. Included were all infants with birth gestation ≥35 weeks, discharged at 4–96 h and receiving care from midwifery-at-home (a 12-h daily, 365-days hospital-based outreach service, supported by hospital paediatricians). Phototherapy was delivered via BiliSoft blanket with treatment thresholds determined by standard nomograms. The main outcomes of interest were unplanned readmissions, and cost-effectiveness based on hospital finance department actual costs. Also examined were parental compliance, device issues and safety.

Results: During 2019, 4308 infants received home jaundice surveillance with 86% hospital-discharged before 72 h, 82% exclusively breastfed and 69% having overseas-born mothers. Four hundred infants received HPT, comprising 101 continuing from inpatient phototherapy (IPT), 56 rebounding after IPT, and 243 home-diagnosed as needing phototherapy and triaged to HPT. Only 1 of 400 (0.25%) HPT infants required readmission. Additionally, there were 80 home-diagnosed jaundiced infants triaged to immediate readmission for IPT. Maximal serum bilirubin was 454 μmol/L. No exchange transfusion, encephalopathy or HPT-device problems occurred. An early 2019 bilirubin analyser upgrade resulted in higher bilirubin readings and some unintended subthreshold phototherapy. Supported by midwives, most parents managed HPT with ease. HPT cost $640/day compared to $2100/day for infant IPT readmission and $1000/day for a longer birth-admission stay. Up to 2 weeks' midwifery-at-home care for the whole cohort cost $2 m less than a 2-day longer birth-admission stay.

Conclusion: Large-scale, midwifery-led, paediatrician-overseen jaundice surveillance and HPT can achieve very low unplanned readmission rates and be cost-effective.

Key words: bilirubin; home; infant; jaundice; midwifery; phototherapy.

What is already known on this topic

1 Neonatal jaundice is very common.
2 Phototherapy is the first-line therapy, with treatment thresholds determined by risk assessment and gestational-age/newborn-age nomograms.
3 Studies examining large-scale, routine, midwifery-led, home jaundice surveillance and HPT administration are lacking.

What this paper adds

1 Large-scale, midwifery-led, paediatrician-overseen, home jaundice surveillance and HPT are feasible and clinically effective. With appropriate triage and oversight, very low rates of unplanned infant readmission can be achieved.
2 Both comprehensive home surveillance of the early post-natal mother and infant and HPT for the individual jaundiced infant can be cost-effective compared to similar hospital-based care.

Neonatal jaundice is common, occurring in 60–80% of term and late preterm infants.[1] It is mostly physiological jaundice but can occasionally be due to haemolysis or other pathology. Jaundice constitutes the most common reason for infant readmission in the first weeks of life.[2] Severe hyperbilirubinaemia (variably defined as >425, 450 or 510 μmol/L) occurs in 4 to 42 per 100 000 infants in high-resource countries,[3,4] while chronic bilirubin encephalopathy (kernicterus), occurs in 0.5–2.3 per 100 000 infants. Minimising these harms requires systematic risk stratification using clinical and transcutaneous bilirubinometry assessment, supplemented by serum bilirubin assessment as indicated. Physiological jaundice begins 24 h after birth, peaks on

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days 3–7, then usually reduces.[1,5,6] Current Australian birth data indicate that over two-thirds of newborns are discharged within 3 days of birth.[7] Therefore, jaundice in term infants is often diagnosed after discharge, including 70–80% of those with severe hyperbilirubinaemia.[3,4] Readmissions for jaundice have consequently increased.[2]

Phototherapy is the established first-line treatment for jaundice. First described in 1958,[8] it was initially delivered solely via overhead halogen or fluorescent lights in hospital nurseries. Several papers from the mid-1980s also describe home phototherapy (HPT) using such devices.[1,2] Around 1990, fibre-optic 'blanket' type phototherapy devices[3–5] were developed, later enhanced by light-emitting diode technology.[6] These permitted the delivery of term and late-preterm infant phototherapy at the mother's bedside in post-natal wards, avoiding mother–infant separation and allowing uninterrupted breastfeeding. Their convenience also potentially facilitated HPT expansion, allowing earlier hospital discharge and reducing newborn readmissions.[3,7] However, decades later, publications about HPT remain few.[8–11] Similarly, national guidelines remain cautious. The UK national guideline is silent on HPT,[12] the current US guideline[13] advises HPT only for subthreshold jaundice, and our local state guideline[14] reports insufficient evidence of safety. Debate also exists around the feasibility and resource-effectiveness of HPT.[15]

Since 2006, our hospital-based outreach midwives, overseen by paediatricians, have managed unconjugated, mild- or non-haemolytic jaundice in infants of birth gestation ≥35 weeks at home, as part of our routine early post-discharge care for mother and infant. This includes provision of HPT first initiated at home, and HPT continued or reinitiated after inpatient phototherapy (IPT). The study's aim was to expand the body of knowledge around HPT by evaluating unplanned readmissions, cost-effectiveness and other outcomes of this programme.

Methods

We conducted a retrospective cohort study over the calendar year 2019 at a multicultural Australian tertiary hospital, where 80% of mothers and newborns routinely receive midwifery-at-home visits following hospital discharge.

Clinical data sources comprised the prospectively completed maternity database (eMaternity) and individual electronic medical records.

Inclusion criteria and outcomes of interest

The midwifery-at-home programme is funded to routinely provide up to 2 weeks' post-natal care to all local-catchment mothers and infants with birth gestation ≥35 weeks and hospital discharge between 4 and 96 h after birth. All infants born during 2019 meeting these criteria and receiving at least one home visit from the midwifery-at-home service were included in the study. Infants discharged beyond 96 h represent a lower-risk group receiving indicated, not routine, visits and were not included.

The main outcomes of interest were unplanned hospital readmission among infants triaged as suitable for HPT, and cost-effectiveness. We also explored parental HPT compliance, device-related safety issues (defined as any complication requiring premature HPT discontinuation) and jaundice safety issues (including bilirubin >450 μmol/L, exchange transfusion and bilirubin encephalopathy).

Midwifery-at-home model of care

The model involved hospital birth followed by discharge into the midwifery-at-home service which operated 12 h daily (8 am–8 pm), 365 days a year. Total staffing comprised approximately 15.4 full-time-equivalent (FTE) midwifery staff, plus a 0.6 FTE manager and a 0.6 FTE administrative support position. Daily staffing involved eight to nine midwives who worked 8.5-h shifts, with two starting late morning to provide cover till 8 pm. For concerns arising between visits, parents could phone the service 8 am–8 pm daily. For phototherapy device-related advice outside these hours, they could contact the post-natal ward. For urgent concerns about the infant, they were advised to attend the nearby Children's Hospital. Prior diary data demonstrated that approximately 25% of midwifery-at-home visit time involved jaundice surveillance, with or without HPT provision.

Phototherapy initiation thresholds

Jaundice management (risk assessment, clinical review, transcutaneous bilirubinometry and serum bilirubin) followed the NSW Health Guideline 2016.[14] Gestational-age and newborn-age bilirubin treatment threshold nomograms identical to those of the National Institute for Health and Care Excellence Guideline 2010[12] were used. Phototherapy thresholds were the same for IPT and HPT.

Phototherapy initiated (or reinitiated) at home

Infants diagnosed at home with jaundice above the phototherapy threshold were risk-stratified according to the presence or absence of known jaundice risk factors as per the NSW Health Guideline.[14] Hyperbilirubinaemia in the first 24 h, serum bilirubin levels ≥50 μmol/L above treatment threshold or a rise of ≥8.5 μmol/L/h required readmission while other factors were individually assessed. With adequate infant feeding and no risk factors, a midwife could initiate HPT without paediatric consultation. However, paediatric consultation always occurred with haemolysis risk factors, maternal diabetes, perinatal asphyxia, extravascular blood collection, sibling history of jaundice needing phototherapy, or concerns about feeding or thermoregulation. After assessment and consultation, a decision was made regarding the appropriateness of HPT versus readmission. The family's possible compliance limitations (social and language) were also taken into account. Phone interpreters were used, when required, to explain general matters and bilirubin results, but households with no one speaking sufficient English to safely manage HPT were triaged to readmission rather than HPT.

HPT was delivered via BiliSoft Blanket (GE Healthcare, Chicago, IL, USA), a fibre-optic light-emitting diode blanket. Only the large blanket with irradiance of 35 $\mu W/cm^2/nm$[16] was used. The 12 units were maintained and tested according to the manufacturer's specification. Disposable covers for the blanket, eye covers and thermometers were provided to parents.

Home visits likely to involve bilirubin testing routinely occurred first in the day. Correct specimen handling including

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the use of amber-coloured, light-protected sample tubes, early transport to the laboratory and processing prioritisation was routine. Following lab analysis, results review, paediatrician consultation, family education and HPT set-up, HPT typically started between 4 pm and 6 pm. The first progress bilirubin sample was collected at 8 am the next day. During HPT, home visits and bilirubin tests were undertaken daily (rarely, twice daily).

Birth-admission IPT continuing as HPT and readmission IPT

Birth-admission IPT usually occurred at the mother's post-natal bedside using a BiliSoft Blanket. If the infant's serum bilirubin remained above treatment threshold when the mother was ready for discharge, a decision was made regarding the relative suitability of ongoing IPT versus transition to HPT. Factors considered include both the trajectory and actual level of serum bilirubin. Readmission IPT occurred in the special care nursery, often using both BiliSoft and overhead lights.[17]

Parent HPT training and compliance

For HPT, either the midwife delivered the phototherapy unit or the partner collected it from the hospital. Face-to-face instruction, written information (including language-specific general jaundice information) and a video link were provided. Families were instructed to keep the phototherapy device on the infant at all times, except during nappy change. Phototherapy hours, infant feeds and output, and axillary temperature during each feed were recorded. A detailed review of every file over a 4-month period was undertaken to explore parental compliance issues.

Serum bilirubin analyser

Total serum bilirubin results were analysed by the hospital laboratory's leading-brand commercial analyser. In early 2019 (the study period), a diazo-based bilirubin analyser was replaced by a vanadate-oxidation-based analyser as part of an upgrade (same manufacturer). Laboratory quality assurance testing subsequently reported that, while the diazo method ran close to target values, the vanadate-oxidation method showed around 10% positive bias (i.e. reported bilirubin levels as 10% higher). The manufacturer is addressing this.

Economic analysis

Australian public hospitals are funded according to an activity-based funding model.[18] After each financial year, using government activity-based management portals, hospital finance departments retrospectively calculate the cost of each inpatient and outpatient service. Included in the calculation are all infrastructure and equipment purchase and maintenance costs, utilities, pathology and imaging, medications, staff salary costs including entitlements, and a portion of overall hospital costs. Patient numbers and lengths of stay then determine an average patient cost per treatment day or per episode of care for each particular treatment. Our paper reports actual healthcare costs for the Australian financial year 1 July 2019 to 30 June 2020 as supplied by the hospital finance department.

Statistical analysis

The recorded data were collectively run as an archetype report and were saved in an Excel spreadsheet database (Microsoft Corporation, Redmond, WA, USA). The data were then analysed using SPSS for Windows Release 26.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were used to summarise demographic and outcomes data. Categorical baseline characteristics and outcomes of interest were summarised with a relative risk and 95% confidence interval and compared between the groups using a χ^2 test (or the Fisher exact test, where applicable). The independent samples *t*-test was used to assess continuous non-skewed (parametric) variables; these are presented as means with standard deviations. For skewed ordinal data (non-parametric), the Mann–Whitney *U* test was used; these data are presented as medians with interquartile ranges. A *P* value <0.05 was considered statistically significant.

Ethics

Ethics approval was obtained from the local health district human research committee (approval number: 2004-05 QA).

Results

Overview

Over the 2019 year, there were 5457 births, of which 4308 (79%) met eligibility criteria for the study (Fig. 1). In the study cohort, 86% were discharged within 72 h, the exclusive breastfeeding rate was 82%, and 69% of mothers were overseas-born. A total of 641 infants (14.9%) received phototherapy. Phototherapy was more common in first-born, male, Asian, younger-gestation infants and following instrumental vaginal birth (Table 1). Of the 641 infants, 241 received IPT only (161 before hospital discharge and 80 home-diagnosed and triaged to readmission). Four hundred received HPT (101 continuing from hospital IPT, 56 rebounding after hospital IPT and 243 home-diagnosed and triaged to HPT) (Fig. 1, Table 2).

Total hospital and HPT hours were 30 716, with almost two-thirds (19 862 h) provided at home (Table 2). Total midwifery-at-home episodes of care were approximately 40 000. There were just over 28 000 home visits for mother and infant (14 000 each), while the remaining episodes (almost 12 000) comprised phone consultations with the mother/family, phone consultations with paediatricians and collection of blood from infants. The mean number of midwifery-at-home visits overall was 3.3 (range 1–14) with mean home-collected bilirubin tests 0.6 per infant (range 0–9).

Hospital-initiated phototherapy: HPT for continuers and rebounders

One hundred and one infants continued IPT (median duration 22 h) into HPT (median 45 h). No 'continuer' required hospital readmission. Fifty-six of 217 infants (26%) who had completed hospital-initiated phototherapy before discharge (median 25 h) required home re-initiation of phototherapy for rebound jaundice (median 50 h). The only significant difference between the rebound *versus* no-rebound cohorts was birth gestation (37 + 2 vs. 38 + 4 weeks). No 'rebounder' required hospital readmission.

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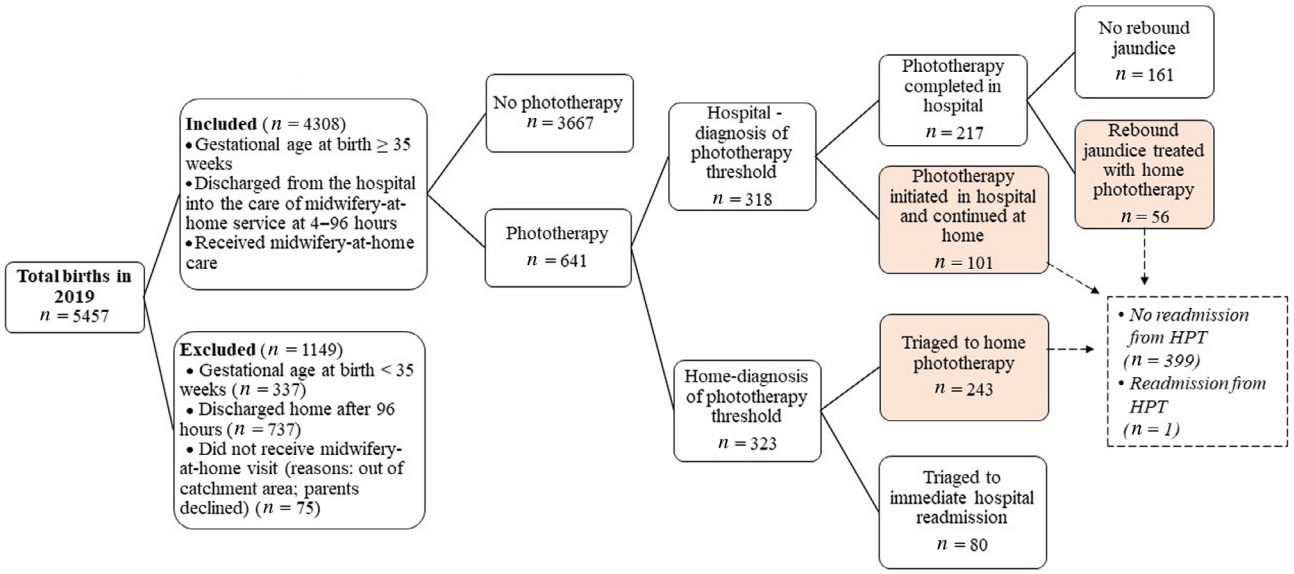

Fig. 1 Flowchart of study participants.

Home-diagnosed phototherapy threshold: Triaged to HPT or hospital readmission

Jaundice requiring phototherapy was diagnosed for the first time at home in 323 infants. Of these, 243 (75%) were triaged as suitable for HPT while 80 (25%) were triaged to hospital readmission (Table 3). Of these readmissions, 73 were for clinical indications and seven (8.8%) because of English language limitations.

Infants triaged to readmission were significantly more likely to be direct antibody test positive, have maternal blood group O and have serum bilirubin ≥300 μmol/L. However, 20 out of 42 of the direct antiglobulin test positive infants and 5 out of 6 glucose-6-phosphate-dehydrogenase-deficient infants were treated at home. Four readmitted infants had maximum bilirubin levels over 400 μmol/L, including one above 450 μmol/L (454 μmol/L); the latter occurred after the bilirubin analyser change.

Readmitted infants required only phototherapy, plus supplementary feeding and rehydration. No infant suffered any morbidity, none required exchange transfusion, and none had bilirubin encephalopathy. Of those triaged to readmission, the final diagnosis was physiological jaundice in 56 of 80 (70%), ABO incompatibility in 20 of 80 (25%), and one case each of glucose-6-phosphate-dehydrogenase deficiency, Rhesus blood group incompatibility, polycythaemia and indeterminate diagnosis.

Among the 243 home-diagnosed infants triaged to HPT, there was only one brief readmission, on day 12 for prolonged physiological jaundice. Of the combined 400 infants who received HPT, this also constituted the only readmission (0.25%). No complications with the HPT device occurred.

Parent compliance issues

Few parents experienced difficulty managing HPT. Of the 400 receiving HPT, the detailed 4-month file audit found that 7 of 130 (5.4%) had a midwifery-at-home medical record entry noting parents were initially leaving the HPT off at times other than during nappy change. Additional education remedied this, and no readmissions resulted from it.

Cost analysis

Finance department actual costs are shown in Table 4. For the 400 jaundiced infants, HPT ($640/day) was almost $1 million less expensive than readmission for IPT ($2100/day) or a prolonged birth-admission stay ($1000/day) would have been. For the entire 4300 mother–infant cohort, the midwifery-at-home programme cost about $6.6 m for 40 000 episodes of care. This was approximately $2 million less expensive than if mothers and infants had remained in hospital for two additional birth-admission days ($8.6 m).

Discussion

Clinical assessment of home jaundice surveillance and therapy

In this retrospective cohort study, a midwifery-at-home model of care for neonatal jaundice surveillance and management was found to have very low unplanned readmission rates. Over 4300 infants received jaundice surveillance at home and almost two-thirds of phototherapy hours were delivered at home. Four hundred infants received HPT based on internationally recognised risk-assessment and bilirubin nomograms,[12] while 80 infants diagnosed at home as needing phototherapy were triaged as unsuitable for HPT and immediately readmitted.

One infant triaged to immediate readmission met the criteria for severe hyperbilirubinaemia (454 μmol/L); this occurred after the bilirubin analyser change. No infant suffered morbidity and

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Table 1 Maternal and neonatal characteristics of newborns and risk of receiving phototherapy†

	Total cohort ($n = 4308$)	No phototherapy ($n = 3667$)	Phototherapy ($n = 641$)	*P* value	RR (95% CI)
Maternal					
Age, years, mean ± SD (range 16–51)	31 ± 5	31 ± 5	32 ± 5	0.320	0.21‡ (−0.22, 0.62)
Overseas-born, *n* (%)	2987 (69)	2490 (68)	497 (78)	<0.001	1.07 (1.04–1.10)
Ethnicity, *n* (%)§					
Aboriginal/Torres Strait Islander/Pacific Islander	105 (2)	88 (2)	17 (3)	0.702	1.09 (0.70–1.70)
Caucasian	1103 (26)	976 (27)	127 (20)	<0.001	0.72 (0.60–0.86)
Middle Eastern/African	1165 (27)	1039 (28)	126 (20)	<0.001	0.66 (0.55–0.79)
Southern and Central Asian	1003 (23)	828 (23)	175 (28)	0.009	1.24 (1.06–1.45)
Asian (North Eastern and South Eastern)	932 (22)	736 (20)	196 (31)	<0.001	1.60 (1.37–1.86)
Maternal diabetes, including diet-controlled GDM, *n* (%)	737 (17)	619 (17)	118 (18)	0.343	1.02 (0.98–1.05)
Singleton pregnancy, *n* (%)	4240 (98)	3613 (99)	627 (98)	0.182	1.07 (0.95–1.21)
Neonatal					
Mode of birth, *n* (%)					
Spontaneous vaginal birth	2648 (62)	2269 (62)	379 (59)	0.187	0.91 (0.78–1.05)
Instrumental birth	466 (11)	356 (10)	110 (17)	<0.001	1.71 (1.43–2.05)
Caesarean section	1194 (28)	1042 (28)	152 (24)	0.014	0.81 (0.68–0.96)
Firstborn infant, *n* (%)	1695 (39)	1375 (38)	320 (50)	<0.001	1.54 (1.33–1.77)
Male gender, *n* (%)	2181 (51)	1811 (49)	370 (58)	<0.001	1.33 (1.15–1.54)
Gestational age at birth, weeks + days, mean ± SD	$39^{+1} \pm 1^{+1}$	$39^{+2} \pm 1^{+1}$	$38^{+4} \pm 1^{+3}$	<0.001	−0.83‡ (−0.93, 0.74)
Gestational age at birth, weeks, *n* (%)					
35–36	116 (3)	54 (2)	62 (10)	<0.001	3.87 (3.21–4.66)
37–38	1217 (28)	926 (25)	291 (45)	<0.001	2.11 (1.84–2.43)
≥39	2975 (69)	2687 (73)	288 (45)	<0.001	0.37 (0.32–0.42)
Feeding at discharge from hospital, *n* (%)					
Exclusive breastfeeding	3542 (82)	3063 (84)	479 (76)	<0.001	0.64 (0.55–0.75)
Formula only	226 (5)	209 (6)	17 (3)	0.001	0.49 (0.31–0.78)
Mixed feeding	492 (11)	354 (10)	138 (22)	<0.001	2.13 (1.81–2.51)
Missing data	48 (1)	41 (1)	7 (1)	—	—
Birth weight, g, mean ± SD (range 2010–5410)	3337 ± 455	3360 ± 450	3206 ± 458	<0.001	−153.90‡ (−192, 116)
Weight loss ≥10% by day 4	422 (10)	350 (10)	72 (11)	0.284	1.13 (0.79–1.42)
Age at post-birth hospital discharge, h, mean ± SD (range 4–96)	47 ± 23	45 ± 23	56 ± 24	<0.001	10.78‡ (8.87–12.68)
Age at post-birth hospital discharge, h, *n* (%)					
≤72	3688 (86)	3237 (88)	451 (71)	<0.001	0.41 (0.35–0.47)
73–96	620 (14)	434 (12)	186 (29)	<0.001	1.25 (1.19–1.32)

† Values may not add up to 100 due to rounding.
‡ Mean difference.
§ Ethnicity is assumed from country of birth and is classified according to Australian Standard Classification of Cultural and Ethnic Groups (ASCCEG), 2019 | Australian Bureau of Statistics (abs.gov.au): Caucasian includes Western European, Northern European, Southern and Eastern European and Americas; Middle Eastern/African includes all African countries; Southern Asian includes Indian Subcontinent; Central Asian includes Afghanistan, Armenia, others; Asian includes South-East Asian (e.g. Philippines, Vietnam) and North-East Asian (China, Korea).
CI, confidence interval; GDM, gestational diabetes; RR, relative risk; SD, standard deviation.

none needed exchange transfusion or developed bilirubin encephalopathy. There were no complications from the HPT device itself.

Of the 400 infants receiving HPT, there was only one readmission (0.25%), for prolonged physiological jaundice on day 12. This compares favourably with the 1.9–4% shown in recent HPT studies.[9–11] These results were achieved within a cohort of infants of gestational age down to 35 weeks, having early hospital discharge and high rates of exclusive breastfeeding, all recognised risk factors for jaundice and/or readmission.[12–14,19]

One potential limitation of HPT is that it cannot easily comply with guideline recommendations regarding bilirubin measurement frequency during phototherapy. While measurement

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Table 2 Summary of home visits, bilirubin tests and phototherapy hours for entire cohort ($n = 4308$)

Status	Number in each group (% of total cohort)	No. of home visits; mean ± SD (range)	Total No. bilirubin tests in hospital; mean ± SD (range)	Total No. bilirubin tests at home; mean ± SD (range)	Total hours of IPT; median (IQR)	Total hours of HPT; median (IQR)
No phototherapy	3667 (85)	11 174; 3.1 ± 1.6 (1–12)	248; 0.1 ± 0.3 (0–3)	494; 0.1 ± 0.6 (0–8)	—	—
Phototherapy threshold diagnosed in hospital All phototherapy delivered as IPT No rebound jaundice	161 (4)	434; 2.7 ± 1.6 (1–11)	487; 3.0 ± 1.3 (1–9)	199; 1.2 ± 1.0 (0–1)	4723; 25 (21–37)	—
Phototherapy threshold diagnosed in hospital Phototherapy initiated as IPT and continued as HPT	101 (2)	449; 4.5 ± 2.2 (2–13)	219; 2.3 ± 1.0 (1–6)	318; 3.1 ± 1.5 (0–8)	1984; 22 (5–29)	4268; 45 (24–56)
Phototherapy threshold diagnosed in hospital IPT initiated and completed in hospital. Rebound jaundice diagnosed at home and treated with HPT	56 (1)	355; 6.3 ± 2.0 (1–11)	188; 3.4 ± 1.3 (2–8)	242; 4.3 ± 1.3 (0–7)	1657; 25 (20–38)	3340; 50 (46–73)
Phototherapy threshold diagnosed at home Triaged to HPT	243 (6)	1507; 6.2 ± 2.2 (1–14)	53; 0.2 ± 0.7 (0–9)	1113; 4.6 ± 1.7(1–9)	11†; 0 (0–0)	12 254; 48 (27–58)
Phototherapy threshold diagnosed at home Triaged to immediate readmission for IPT	80 (2)	346; 4.3 ± 2.3 (1–12)	180; 2.3 ± 1.6 (2–8)	193; 2.4 ± 1.3 (1–6)	2479; 24 (21–40)	—
Total	4308 (100)	14 265; 3.31 ± 1.87 (1–14)	1375; 0.32 ± 0.93 (0–9)	2559; 0.59 ± 1.43 (0–9)	10 854 (0–40)	19 862 (0–73)

† One infant triaged to HPT was readmitted on day 12 for prolonged physiological jaundice and received 11 h of IPT.
HPT, home phototherapy; IPT, inpatient phototherapy; IQR, interquartile range; SD, standard deviation.

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Table 3 Home diagnosis of phototherapy threshold – Risk of triage to readmission and inpatient phototherapy (IPT) versus triage to home phototherapy†

	Triaged to HPT (n = 243)	Triaged to immediate readmission and IPT (n = 80)	P value	RR (95% CI)
Maternal				
Overseas-born, *n* (%)	191 (79)	63 (79)	0.977	1.00 (0.86–1.17)
Rhesus negative mother, *n* (%)	10 (4)	6 (8)	0.226	1.56 (0.80–3.02)
Blood group O mother, *n* (%)	91 (37)	45 (56)	0.003	1.77 (1.21–5.59)
Neonatal				
DAT positive, *n* (%)	20 (8)	22 (28)	<0.001	2.54 (1.76–3.67)
G6PD deficient, *n* (%)	5 (2)	1 (1)	1.000‡	0.67 (0.11–4.04)
GA at birth (weeks + days), mean ± SD	$38^{+6} \pm 1^{+1}$	$38^{+4} \pm 1^{+2}$	0.039	−0.32§ (−0.63–0.00)
Birth weight, g, mean ± SD (range 2270–4670)	3228 ± 423	3347 ± 443	0.032	119§ (10.12–227.27)
Weight loss ≥10% by day 4, *n* (%)	32 (13)	12 (16)	0.601	1.15 (0.68–1.96)
Age at post-birth hospital discharge, h, median (IQR) (range 4–96)	40 (26–51)	41 (26–58)	0.846	–
Age at phototherapy initiation, h, median (IQR) (range 30–268)	79 (62–109)	90 (69–119)	0.070	–
Total serum bilirubin at phototherapy decision, μmol/L, mean ± SD (range 125–454)	290 ± 46	309 ± 62	0.003	19.51§ (6.75–32.27)
Total serum bilirubin at phototherapy decision, μmol/L, *n* (%)				
<200	7 (3)	6 (8)	0.074	1.93 (1.04–3.60)
200–299	127 (52)	22 (28)	<0.001	0.44 (0.29–0.69)
300–399	109 (45)	48 (60)	0.019	1.57 (1.07–2.34)
≥400	0	4 (5)	<0.001	
Total hours of home phototherapy, median (IQR) (range 0–210 h)	48 (28–59)	–	–	–
Total hours of hospital phototherapy, median (IQR) (range 0–98 h)	0 (0–0)¶	24 (21–40)	–	–

† Values may not add up to 100 due to rounding.
‡ Fisher's exact test.
§ Mean difference.
¶ One infant triaged to HPT was readmitted on Day 12 for prolonged physiological jaundice and received 11 h of IPT.
CI, confidence interval; DAT, direct antibody test; G6PD, glucose-6-phosphate dehydrogenase deficiency; GA, gestational age; HPT, home phototherapy; IQR, interquartile range; RR, relative risk; SD, standard deviation.

within 6–8 h of phototherapy initiation is advised,[12,14] first treatment measurement generally occurred after 14–16 h in our study. While the cohort size is underpowered to assess rare outcomes such as encephalopathy, the results support the current model of risk-based triage.

Cost-effectiveness

The HPT cost was threefold lower than infant readmission or longer birth-admission for IPT. That HPT is cost-effective compared to hospital phototherapy has been demonstrated previously.[1,7,10] Of equal importance, up to 2 weeks' midwifery-at-home surveillance and care for the entire 4300 mother–infant cohort was approximately $2 m cheaper than a 2-day longer birth-admission stay, which is the minimum additional stay likely required in the programme's absence.

Importance of parental support during HPT

Supported by midwives, the majority of parents managed the phototherapy device easily. Despite phototherapy being more common in infants of overseas-born mothers and 8.8% of triaged readmissions being language-indicated, infants of overseas-born mothers were not overall more likely to be readmitted. Of infants receiving HPT, 5.4% of parents needed further education about keeping the blanket on continuously except during nappy change. Clinician support in the home has likewise been demonstrated by others to be integral to the safety of HPT.[7,9] In comparison, requiring the family to attend daily for hospital review appears more hazardous.[11]

Strengths and weaknesses

Previous studies describing HPT have focused on home management of jaundiced infants by paediatric nurses not involved in

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Table 4 (a) Cost difference of home phototherapy (HPT) versus inpatient phototherapy (IPT) for 400 jaundiced infants. (b) Cost difference of surveillance and care via midwifery-at-home versus 2 additional days of birth-admission stay for 4300 mothers/infants

(a) Phototherapy treatment	Cost per treatment day	Cost of 2 days† treatment	Total cost	Cost difference IPT versus HPT
If received HPT ($n = 400$ infants)	\$640/day comprising: Infant home visit \$190 Mother home visit \$150 Other care episodes \$150 × 2 daily	\$512 000	\$0.51 m	\$0.95 m Favoured HPT over IPT
If received IPT ($n = 400$ infants) • Infant readmission ($n = 243$ home-initiators) ($n = 56$ home rebounders)	\$2100/day (IPT in SCN)	\$1 255 800	\$1.46 m	
• Longer birth-admission stay for mother and infant ($n = 101$ continuers)	\$1000/day‡ (IPT in post-natal ward at mother's bedside beyond usual stay for labour/birth/early post-natal care)	\$202 000		

(b) Model of care	Duration of care	Cost of care	Total cost of care	Cost difference M@H programme versus 2 days longer post-natal stay
Midwifery at home ($n = 4300$ women/infants)	Up to 2 weeks' home care	40 000 episodes of care = 14 000 infant home visits (\$190 each = \$2.66 m) +14 000 mother home visits +12 000 other care episodes (\$150 each = \$3.9 m)	\$6.6 m	\$2 m Favoured midwifery-at-home over 2-day longer birth-admission inpatient stay
Longer birth-admission stay for mother and infant (n = 4300 women/infants)	2 additional days of mother/infant inpatient post-natal stay for surveillance and care beyond the usual stay for labour/birth/early post-natal care‡	Costed at \$1000/day‡	\$8.6 m	

Costs were provided by the hospital finance department for the Australian Financial Year July 2019 to June 2020. Costs are in Australian Dollars, rounded up to nearest \$10.
† Median HPT for home initiators was 48 h, rebounders 50 h, continuers 45 h. While IPT in SCN can be of shorter duration (combined therapy), a 2-day readmission is common.
‡ Birth-admission cost for the average 3-day mother/infant stay (labour/birth/early post-natal; all types of birth) was \$7100. Thereafter, post-natal stay cost was approximately \$1000/day.
HPT, home phototherapy; IPT, inpatient phototherapy; M@H, midwifery-at-home; SCN, special care nursery.

providing care to the mother.[7,9,10] Our study describes a uniquely holistic model of care, where the surveillance and management of neonatal jaundice is part of the overall midwifery-led care for women who have recently given birth and their infants. A second strength is a cost-effectiveness analysis that looks beyond the individual jaundiced infant to an entire care model. Finally, these results were achieved within a highly diverse multicultural population.

The limitations of our study include its retrospective nature and being underpowered for the detection of rare safety outcomes. We also lacked patient satisfaction data; however, others have clearly demonstrated HPT's popularity with parents.[7,9] Additionally, while our clinical study covered the calendar year 2019, finance department costings were for the financial year July 2019 to June 2020. Numbers will always vary slightly from year to year and we have provided rounded approximate costs to accommodate that.

One special and cautionary limitation relates to the 2019 laboratory analyser change which reported 10% higher serum bilirubin levels and was associated with a phototherapy rate of 15% in this study. Our usual phototherapy rate is around 8–9%, not dissimilar from others.[20] A group from California reported a similar significant recalibration-associated impact, where a modest decrease in mean bilirubin of 21 μmol/L reduced phototherapy rates by over half (4.5% vs. 9.3%).[21] Bilirubin analyser measurement standardisation is therefore crucial to appropriate jaundice care.

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Conclusion

The principal goal of phototherapy is to avoid the harms of severe hyperbilirubinaemia. A second important goal is to manage jaundice, as far as possible, without separating mother and infant. While acknowledging the larger numbers needed to exclude rare adverse events, our results suggest both goals can be achieved within a midwifery-led, paediatrician-supervised home jaundice surveillance and treatment programme. Such a programme can also be cost-effective.

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