Maternal heart rate during the first 48 h postpartum

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Title: Maternal heart rate during the first 48 hours postpartum: A retrospective cross sectional study

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66 Manchester
67 M13 9WL
68
Introduction

Throughout pregnancy and the puerperium significant cardiovascular changes occur. Maternal heart rate increases by approximately 20% from the pre-conception baseline to the third trimester of pregnancy (1, 2), with a further increase during labour (3). Whilst these changes are well understood, the changes in the postpartum period are less well defined. Studies show maternal heart rate returns to baseline weeks to months post-delivery (4-7), yet the early postpartum period remains poorly described. Knowledge of what constitutes normal during this period is clinically pertinent to facilitate identification of sick women, and avoid inappropriate investigation of healthy women. In some cases the cause of postpartum tachycardia is evident (haemorrhage, sepsis)(8-12). In other cases it is less obvious and should prompt further investigation for causes such as occult bleeding, cardiac pathology or pulmonary embolism (3, 13-15).

Modified Early Obstetric Warning Scores (MEOWS) are widely used. The parameters used vary (16, 17) and have often been developed from a non-pregnant population. Data derived from a postpartum population would improve the pre-existing MEOWS scores validity; providing a platform for further investigation into the relationship between postpartum heart rate and negative outcomes and ultimately the creation of a postpartum specific clinical assessment tool.

Study Aims

1. Describe the distribution of heart rate in the first 48 hours postpartum (at 6, 12, 24 and 48 hours post-delivery), in women with no evidence of sepsis, haemorrhage or anaemia.

2. Investigate the relationship between postpartum heart rate and other maternal factors (maternal BMI at booking, maternal age, method of delivery, puerperal blood loss, discharge haemoglobin and length of hospital stay).
Materials and Methods

Study Design

Data were collected retrospectively from all women who delivered on the consultant led obstetric unit at Saint Mary’s Hospital, Manchester (a National Health Service tertiary obstetric unit) between 28th July 2012 and 15th June 2015 (from the introduction of electronic observation recording database Patientrack© [Patientack, Sydney, NSW, Australia] to study commencement).

Data Source

Maternal age and BMI at booking, puerperal blood loss, method of delivery, discharge haemoglobin and length of hospital stay were sourced from the maternal database (CMIS, Advance Learning®, Derby, UK). Patient observations (temperature and heart rate observations at 6, 12, 24 and 48 hours postpartum [+/- 1 hour]) were sourced from the electronic vital signs and MEOWS database used in the unit, Patientrack©.

Exclusion Criteria

Women delivering on the midwifery lead unit were not included as their heart rate measurements were not recorded onto Patientrack©. All women in whom tachycardia may have been due to sepsis, haemorrhage or anaemia were excluded. Sepsis was excluded by removing women with a recorded temperature outside of 36-38.3°C during their hospital stay (in line with the International Guidelines on Management of Severe Sepsis & Septic Shock: 2012 (18)). Haemorrhage and anaemia were accounted for by excluding results from women whose puerperal blood loss was ≥ 1,000ml (Royal College of Obstetricians & Gynaecologists’ guidelines for major postpartum haemorrhage (19)) or whose discharge haemoglobin was < 100 g/l (British Society of Haematology guidelines on maternal and postpartum anaemia (20)).
Statistical Analyses

Statistical analyses were performed using IBM® SPSS® Statistics 22 (The International Business Machines Corporation®, New York, NY, USA).

Central tendency for heart rate at each time period postpartum (6, 12, 24 and 48 hours) was calculated using the mean (μ). Spread was calculated using standard deviation (SD) and suggested normal range upper thresholds were calculated using the mean in addition to two and three standard deviations (μ+2SD, μ+3SD).

See Data Grouping below for details on how groups were constructed from continuous variables.

The difference in mean heart rate between groups was assessed for statistical significance using a one way analysis of variance (ANOVA). Scheffe’s test was applied to assess the significance of the difference between the individual subgroups, unless either the variance was heterogeneous among the subgroups or the ANOVA showed a non-significant overall difference.

Groups were correlated with average postpartum heart rate data across all time points (6, 12, 24 and 48 hours) using the Pearson test. Distribution normality was evaluated using histograms. Correlation significance was assessed using a two-tailed test.

Data Grouping

BMI

BMI data were grouped according to the latest NICE guidelines (21) as <18.5 kg/m² (underweight), 18.5-24.9 kg/m² (healthy), 25-29.9 kg/m² (overweight), 30-34.9 kg/m² (obese I), 35-39.9 kg/m² (obese II), >40 kg/m² (obese III).

Delivery method

Delivery method data were grouped into spontaneous vaginal delivery, caesarean section and instrumental vaginal delivery.
According to NHS Health Research Authority (HRA) definitions (22), this study was not considered as research and therefore ethical approval from the NHS HRA or the local ethics board was not required.

Our initial search yielded 16840 heart rate readings from 11401 women. The exclusion criteria for sepsis, haemorrhage and anaemia removed 9207 readings from 6237 women, leaving 7633 heart rate readings from 5164 women. 6 women had erroneous heart rate readings (ranging between 12-18 bpm) with duplicate readings recorded at the same time of values which would be expected. These low values were postulated to be input error by the user recording heart rate and therefore excluded, thus leaving 7627 readings from 5164 women.

Heart rate at time intervals following delivery (6, 12, 24 and 48 hours)

Heart rate was normally distributed at all four time points (Figure 1A-D). The mean heart rate ($\mu$) was 83.6 beats per minute (bpm) at 6 hours, 84.5 at 12 hours, 85.4 at 24 hours and 84.3 at 48 hours (Table 1).

The mean heart rate at 6 hours (83.6) was significantly different to both 12 (84.5, $p=0.041$) and 24 hours (85.4, $p<0.001$).

When mean + 2 standard deviations ($\mu+2SD$) is taken as the upper threshold for the normal range, the respective values are 108.2, 109.4, 110.4 and 109.7 at 6,12, 24 and 48 hours after delivery.

When mean + 3 standard deviations ($\mu+3SD$) is used, the respective values are 120.6, 121.9, 123.0 and 122.4 bpm.

The postpartum time interval cohorts characteristics were compared (Table 2). Significant differences were found in the method of delivery; with a lower proportion (45.0%) of non-
instrumental vaginal deliveries in women at 48 hours (p=0.020) and discharge haemoglobin; with
women at 48 hours having lower discharge haemoglobin (112 g/L) than 6 (114 g/L) and 12 hours
(112 g/L) (p=0.009).

For the following analyses data across all time points were grouped together.

**BMI**

Data for BMI were missing for 191 readings from the 7627, thus leaving 7436 readings across all time
intervals postpartum (6, 12, 24 & 48 hours).

The mean heart rate was 83.2 bpm in underweight, 83.2 ideal weight, 84.9 in overweight, 86.3 in
obese I, 85.1 in obese II and 87.9 in obese III women (Table 3) (p<0.001, observed power =1.000).

There was a significant direct correlation between heart rate and BMI of 0.097 (p<0.001).

**Age**

The mean heart rate was 86.7 in women less than 20 years old, 85.1 in 20-29 years old, 83.6 in 30-39
years old and 84.4 in ≥40 years old (p<0.001, observed power =1.000) (Table 3).

There was a significant inverse correlation between heart rate and age of -0.079 (P<0.001).

**Puerperal blood loss**

Mean heart rate was 85.1 (≤100 ml), 82.6 (100-199), 83.4 (200-299), 83.9 (300-399), 84.7 (400-499),
86.3 (500-599), 84.8 (600-699), 85.6 (700-799), 86.1 (800-899) and 85.8 (900-999), with significant
variation (Table 3) (p<0.001, observed power =1.000). There was no correlation between heart rate
and blood loss.
Discharge haemoglobin

2556 of the heart rate readings had missing entries for discharge haemoglobin. It was not hospital policy to take a postpartum haemoglobin measurement unless indicated. This meant 5071 heart rate readings were analysed for an association with discharge haemoglobin. There was a significant inverse correlation between heart rate and discharge haemoglobin of -.031 (p=0.027), however women with anaemia or severe postpartum haemorrhage were excluded.

Method of delivery

Mean heart rate was highest in women who delivered by an instrumental delivery (85.5) and lowest in women who delivered by spontaneous vaginal delivery (83.9) (p=0.002, observed power =0.975) (Table 3). The mean heart rate for the spontaneous vaginal deliveries was significantly less than Caesarean section (p=0.024) and instrumental vaginal deliveries (p<0.001). This may reflect a relationship with blood loss, demonstrated by a significantly higher mean blood loss in Caesarean section (285 ml) than both instrumental vaginal delivery (230 ml) and non-instrumental vaginal delivery (193 ml) respectively (p<0.001).

Length of stay

There was no significant correlation between heart rate and length of stay.

Comments

This large study describes the distribution of heart rate in the first 48 hours postpartum, in women with no evidence of sepsis, haemorrhage or anaemia. The normal range upper limits (mean + 2SDs and mean + 3 SDs) have also been described. Given previous literature has only described the changes in postpartum maternal heart rate weeks after delivery, this is a novel observation.
Although statistically significant differences in heart rate have been shown between various time points (at 6, 12, 24 and 48 hours) post-delivery, these differences are small and not clinically meaningful.

The first 48 hours after delivery represents a time when significant maternal morbidity and mortality can occur. Women with tachycardia which is not associated with sepsis, haemorrhage or anaemia (unexplained tachycardia) should be investigated for other causes such as occult bleeding, pulmonary embolism and cardiac pathology as these can all cause serious maternal morbidity or death. Conversely, unnecessary investigations can be avoided with a heart rate below the thresholds described and in the absence of other signs/symptoms.

In the cohort of women in hospital at 48 hours, fewer had a normal vaginal delivery (45.0% compared to 52.0%, 54.4% and 52.0% at 6, 12 and 24 hours respectively). Whilst this could influence the heart rate distribution, it is likely that in most maternity units women who have instrumental deliveries or caesarean sections stay in hospital longer than those having non-instrumental vaginal deliveries. Our cohort is therefore likely to represent clinical practice in the UK, and our findings are therefore relevant to clinicians working in UK NHS hospitals.

Our data showed a positive correlation between BMI and heart rate, however there was only 4 bpm difference between the lowest (underweight) and highest (obese III) groups. Thus, with the greater complication risk during pregnancy associated with maternal obesity, obese women with unexplained tachycardia should still be investigated at the same thresholds as non-obese women (23-25). This is pertinent given the association obesity has with maternal mortality and cardiovascular disease (26, 27).

The significantly lower heart rate in those having normal vaginal deliveries, compared to both Caesarean sections and instrumental deliveries respectively, may represent a reduced blood loss (28). This would minimise the deficit of haemoglobin and circulating volume, thus enhancing both
the oxygen carrying capacity of the blood and the cardiac preload. Consequentially, the need for compensatory mechanisms to maintain blood pressure reduces, resulting in a negatively chronotropic effect (29, 30).

Tools which aid early detection of deterioration of patients, such as early warning scores (EWS), have been widely adopted. Physiological differences in pregnancy and postpartum necessitate a specific obstetric EWS(31). Despite development of several modified early obstetric warning scores (MEOWS); including the questionnaire based model from Swanton et al.(16) and the statistical based from Carle et al. (17), there remains no consensus (32, 33) and a postpartum specific EWS has yet been devised. Furthermore, the existing MEOWS have their limitations, with Swanton et al. relying upon expert opinion rather than quantitative data and Carle et al. using an Intensive Treatment Unit cohort; thus likely overestimating the prevalence of both significant pathology and the requirement for multi-organ support compared to an unselected cohort, as used in this study. The results from this study can be used to form the basis for further work to create a postpartum EWS.

**Study Strengths**

This retrospective cross-sectional analysis is the first to describe maternal heart rate in the early postpartum period. This large dataset enabled identification of significant differences in heart rate between several subgroups of postpartum women. Data was sourced retrospectively from initial clinical vital signs recordings as per routine postpartum care for women delivering in our unit. This removed potential bias from data collection, sample selection and the environment in which the readings were taken, strengthening the study’s conclusions transferability.

**Study Limitations**

Although the study provides a sound statistical basis for postpartum EWS development, it has not yet been correlated with outcome measures i.e. morbidity or mortality. Therefore despite being able...
to suggest thresholds for abnormality, this study does not help predict the likelihood of underlying pathology if a tachycardia is detected. Even with a cohort this size, this is not possible since serious maternal morbidity and mortality are rare outcomes.

Each heart rate reading was treated separately, therefore any women with multiple readings would have multiple entries (maximum of 4) for the independent variables (e.g. BMI, age, delivery method etc.) and thus would be over represented within that variable when combining the postpartum heart rate data for all time intervals (6, 12, 24 and 48 hours). Given the significantly lower rate of non-instrumental vaginal deliveries at 48 hours, this may have led to women who had Caesarean section and instrumental vaginal deliveries being overrepresented.

Whilst the study’s dataset size is a strength, it meant statistically significant differences between groups were identified despite small margins. Some of these differences are unlikely to be clinically significant.

Data were collected retrospectively, thus with no standard way of measuring heart rate identified; both electronic and manual recordings were included. However, this reflects past and current practice within the unit.

Use of medication at the time the heart rates were recorded was not considered in this study. Negatively chronotropic drugs such as beta blockers, commonly prescribed to postpartum women with hypertension (34, 35), could lower heart rate and thus skew the data.

All women in the study came from one tertiary centre for obstetrics, where women with pre-existing medical conditions may be overrepresented. Furthermore, this study looked at heart rates up to 48 hours postpartum; the cohort studied at 48 hours in particular, may include a greater proportion of women with medical problems as healthy women with healthy babies may have already been discharged.
**Conclusion**

We have reported heart rate data at 6, 12, 24 and 48 hours postpartum. There is a statistically, but not clinically, relevant difference in maternal heart rate between these time points. We have also suggested upper thresholds of normality at which further clinical investigation should occur.

These findings provide a basis for heart rate parameters to be created for a postpartum EWS. This will aid in the early recognition of women who may develop critical illness or cardiovascular pathology in the postpartum period and provide an opportunity for earlier investigation and intervention. Furthermore, the findings will also support clinicians in avoiding inappropriate investigation, therefore saving resources, facilitating earlier discharge and reducing anxiety for women.

Future work in this area is still required in order to increase the evidence base on postpartum heart rates in other cohorts and to incorporate correlation with poor maternal outcomes into any future postpartum EWS.

**Acknowledgements**

I would like to thank Thomas Drury at the Central Manchester Hospital Trust electronic warehouse, for conducting the data search and providing the data.

**Funding**

This research project was done as part of an undergraduate medical training course and received no external funding.
References


22. HRA. Defining research: your guide to help decide whether your research requires review from a Research Ethics Committee. NHS Health Research Authority; 2013.


Disclosure of interests

There are no competing interests from any of the authors.
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<thead>
<tr>
<th>Time after delivery (hours)</th>
<th>n</th>
<th>Mean Heart Rate (bpm) μ</th>
<th>SD</th>
<th>P Value</th>
<th>μ + 2SD</th>
<th>μ + 3SD</th>
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<td>121.9</td>
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<td>1896</td>
<td>85.4</td>
<td>12.5</td>
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<td>110.4</td>
<td>122.9</td>
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<td>424</td>
<td>84.3</td>
<td>12.7</td>
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<td>109.7</td>
<td>122.4</td>
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<td><strong>Total</strong></td>
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<td><strong>84.4</strong></td>
<td><strong>12.5</strong></td>
<td></td>
<td><strong>109.3</strong></td>
<td><strong>121.8</strong></td>
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</tbody>
</table>

Table 1: Mean (μ), standard deviation (SD) and upper limit of normal (μ+2SD, μ+3SD) maternal heart rate at 6, 12, 24 and 48 hours postpartum.
<table>
<thead>
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<th>Variable</th>
<th>N</th>
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<th>P Value</th>
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</thead>
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<td></td>
<td></td>
<td>6</td>
<td>12</td>
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<tr>
<td><strong>Age (years)</strong></td>
<td>7627</td>
<td>29.9 ± 5.6</td>
<td>29.9 ± 5.6</td>
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<td><strong>BMI (kg/m²)</strong></td>
<td>7436</td>
<td>26.0 ± 6.4</td>
<td>26.0 ± 6.4</td>
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<td><strong>Method of delivery</strong></td>
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<tr>
<td>Non-instrumental vaginal</td>
<td>3999</td>
<td>1391 (52.0)</td>
<td>1432 (54.4)</td>
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<td>Caesarean section</td>
<td>2534</td>
<td>911 (34.0)</td>
<td>833 (31.7)</td>
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<td>Instrumental vaginal</td>
<td>1094</td>
<td>375 (14.0)</td>
<td>365 (13.9)</td>
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<td><strong>Puerperal blood loss (ml)</strong></td>
<td>7627</td>
<td>286 ± 234</td>
<td>288 ± 234</td>
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<tr>
<td><strong>Discharge Hb (g/l)</strong></td>
<td>5071</td>
<td>114 ±10</td>
<td>114 ± 10</td>
</tr>
</tbody>
</table>

Table 2: Baseline characteristics of women split into cohorts according to hours postpartum. Values are mean ± standard deviation or n (%) and compared with one way ANOVA or Chi-squared tests respectively. BMI, body mass index; Hb, haemoglobin.
<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>Mean Heart Rate (bpm) μ</th>
<th>P Value</th>
</tr>
</thead>
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<td><strong>Body mass index (kg/m²)</strong></td>
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<tr>
<td>&lt;18.5 (underweight)</td>
<td>304</td>
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<td>18.5-24.9 (ideal weight)</td>
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<tr>
<td>25-29.9 (overweight)</td>
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<td>30-34.9 (obese I)</td>
<td>1158</td>
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<td>35-39.9 (obese II)</td>
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<td>≥40 (obese III)</td>
<td>196</td>
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<tr>
<td><strong>Maternal age (years)</strong></td>
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<tr>
<td>&lt;20</td>
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<tr>
<td>≥40</td>
<td>346</td>
<td>84.4</td>
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<td>580</td>
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Table 3: The observed effect of potentially confounding factors (body mass index, maternal age, puerperal blood loss, discharge haemoglobin, method of delivery and length of stay) on mean (μ) postpartum heart rate between 6-48 hours.
<table>
<thead>
<tr>
<th>Time postpartum (hours)</th>
<th>Included Cohort</th>
<th>Excluded Cohort</th>
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<tbody>
<tr>
<td></td>
<td>Temperature &gt;38.3, &lt;36 °C</td>
<td>Blood loss ≥1000 ml</td>
</tr>
<tr>
<td>N  μ heart rate (bpm) ± SD</td>
<td>N  μ heart rate (bpm) ± SD</td>
<td>N  μ heart rate (bpm) ± SD</td>
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<tr>
<td>6</td>
<td>2677 83.6 ± 12.3</td>
<td>2144 82.4 ± 13.7</td>
</tr>
<tr>
<td>12</td>
<td>2630 85.5 ± 12.5</td>
<td>1913 83.4 ± 13.7</td>
</tr>
<tr>
<td>24</td>
<td>1896 85.4 ± 12.5</td>
<td>1507 86.7 ± 14.2</td>
</tr>
<tr>
<td>48</td>
<td>424 84.3 ± 12.7</td>
<td>367 85.5 ± 12.6</td>
</tr>
<tr>
<td>Total</td>
<td>7627 84.4 ± 12.5</td>
<td>5931 84.0 ± 13.9</td>
</tr>
</tbody>
</table>

Table 4: Mean (μ) and standard deviation (SD) of maternal heart rate 6, 12, 24 and 48 hours postpartum in the included and excluded cohorts.
Figure 1: Histograms demonstrating the normal distribution of heart rate with x-intercepts at 2 and 3 standard deviations from the mean (A: 6 hours postpartum; B: 12 hours postpartum; C: 24 hours postpartum; D: 48 hours postpartum)

Figure 1: Histograms demonstrating the normal distribution of heart rate with x-intercepts at 2 and 3 standard deviations from the mean (A: 6 hours postpartum; B: 12 hours postpartum; C: 24 hours postpartum; D: 48 hours postpartum)
## STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

<table>
<thead>
<tr>
<th>Item No</th>
<th>Item</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Title and abstract</strong></td>
<td></td>
</tr>
</tbody>
</table>
  \(a\) Indicate the study’s design with a commonly used term in the title or the abstract  
  \(b\) Provide in the abstract an informative and balanced summary of what was done and what was found |
| 2 | **Introduction** | Explain the scientific background and rationale for the investigation being reported |
| 3 | **Objectives** | State specific objectives, including any prespecified hypotheses |
| 4 | **Methods** |  
  \(a\) Present key elements of study design early in the paper |
| 5 | **Setting** | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection |
| 6 | **Participants** |  
  \(a\) Give the eligibility criteria, and the sources and methods of selection of participants |
| 7 | **Variables** | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable |
| 8* | **Data sources/measurement** | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group |
| 9 | **Bias** | Describe any efforts to address potential sources of bias |
| 10 | **Study size** | Explain how the study size was arrived at |
| 11 | **Quantitative variables** | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why |
| 12 | **Statistical methods** |  
  \(a\) Describe all statistical methods, including those used to control for confounding  
  \(b\) Describe any methods used to examine subgroups and interactions  
  \(c\) Explain how missing data were addressed  
  \(d\) If applicable, describe analytical methods taking account of sampling strategy  
  \(e\) Describe any sensitivity analyses |
| 13* | **Results** |  
  \(a\) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed  
  \(b\) Give reasons for non-participation at each stage  
  \(c\) Consider use of a flow diagram |
| 14* | **Descriptive data** |  
  \(a\) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders  
  \(b\) Indicate number of participants with missing data for each variable of interest |
| 15* | **Outcome data** | Report number of outcome events or summary measures |
| 16 | **Main results** |  
  \(a\) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included  
  \(b\) Report category boundaries when continuous variables were categorized  
  \(c\) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period |
| 17 | **Other analyses** | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses |
Discussion

Key results 18
Summarise key results with reference to study objectives

Limitations 19
Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias

Interpretation 20
Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence

Generalisability 21
Discuss the generalisability (external validity) of the study results

Other information

Funding 22
Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.


Maternal heart rate during the first 48 hours postpartum: A retrospective cross sectional study

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12d – N/A
12e – N/A
13a – Lines 142-147
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14b – Tables 1-4
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Title: Maternal heart rate during the first 48 hours postpartum: A retrospective cross sectional study

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Introduction
Throughout pregnancy and the puerperium significant cardiovascular changes occur. Maternal heart rate increases by approximately 20% from the pre-conception baseline to the third trimester of pregnancy (1, 2), with a further increase during labour (3). Whilst these changes are well understood, the changes in the postpartum period are less well defined. Studies show maternal heart rate returns to baseline weeks to months post-delivery (4-7), yet the early postpartum period remains poorly described. Knowledge of what constitutes normal during this period is clinically pertinent to facilitate identification of sick women, and avoid inappropriate investigation of healthy women. In some cases the cause of postpartum tachycardia is evident (haemorrhage, sepsis)(8-12). In other cases it is less obvious and should prompt further investigation for causes such as occult bleeding, cardiac pathology or pulmonary embolism (3, 13-15).

Modified Early Obstetric Warning Scores (MEOWS) are widely used. The parameters used vary (16, 17) and have often been developed from a non-pregnant population. Data derived from a postpartum population would improve the pre-existing MEOWS scores validity; providing a platform for further investigation into the relationship between postpartum heart rate and negative outcomes and ultimately the creation of a postpartum specific clinical assessment tool.

Study Aims
1. Describe the distribution of heart rate in the first 48 hours postpartum (at 6, 12, 24 and 48 hours post-delivery), in women with no evidence of sepsis, haemorrhage or anaemia.

2. Investigate the relationship between postpartum heart rate and other maternal factors (maternal BMI at booking, maternal age, method of delivery, puerperal blood loss, discharge haemoglobin and length of hospital stay).
Materials and Methods

Study Design

Data were collected retrospectively from all women who delivered on the consultant led obstetric unit at Saint Mary’s Hospital, Manchester (a National Health Service tertiary obstetric unit) between 28th July 2012 and 15th June 2015 (from the introduction of electronic observation recording database Patientrack© [Patientack, Sydney, NSW, Australia] to study commencement).

Data Source

Maternal age and BMI at booking, puerperal blood loss, method of delivery, discharge haemoglobin and length of hospital stay were sourced from the maternal database (CMIS, Advance Learning®, Derby, UK). Patient observations (temperature and heart rate observations at 6, 12, 24 and 48 hours postpartum [+/ - 1 hour]) were sourced from the electronic vital signs and MEOWS database used in the unit, Patientrack©.

Exclusion Criteria

Women delivering on the midwifery lead unit were not included as their heart rate measurements were not recorded onto Patientrack©.

All women in whom tachycardia may have been due to sepsis, haemorrhage or anaemia were excluded. Sepsis was excluded by removing women with a recorded temperature outside of 36-38.3°C during their hospital stay (in line with the International Guidelines on Management of Severe Sepsis & Septic Shock: 2012 (18)). Haemorrhage and anaemia were accounted for by excluding results from women whose puerperal blood loss was ≥ 1,000ml (Royal College of Obstetricians & Gynaecologists’ guidelines for major postpartum haemorrhage (19)) or whose discharge haemoglobin was < 100 g/l (British Society of Haematology guidelines on maternal and postpartum anaemia (20)).
Statistical Analyses

Statistical analyses were performed using IBM® SPSS® Statistics 22 (The International Business Machines Corporation®, New York, NY, USA).

Central tendency for heart rate at each time period postpartum (6, 12, 24 and 48 hours) was calculated using the mean (μ). Spread was calculated using standard deviation (SD) and suggested normal range upper thresholds were calculated using the mean in addition to two and three standard deviations (μ+2SD, μ+3SD).

See Data Grouping below for details on how groups were constructed from continuous variables.

The difference in mean heart rate between groups was assessed for statistical significance using a one way analysis of variance (ANOVA). Scheffe’s test was applied to assess the significance of the difference between the individual subgroups, unless either the variance was heterogeneous among the subgroups or the ANOVA showed a non-significant overall difference.

Groups were correlated with average postpartum heart rate data across all time points (6, 12, 24 and 48 hours) using the Pearson test. Distribution normality was evaluated using histograms.

Correlation significance was assessed using a two-tailed test.

Data Grouping

BMI

BMI data were grouped according to the latest NICE guidelines (21) as <18.5 kg/m² (underweight), 18.5-24.9 kg/m² (healthy), 25-29.9 kg/m² (overweight), 30-34.9 kg/m² (obese I), 35-39.9 kg/m² (obese II), >40 kg/m² (obese III).

Delivery method

Delivery method data were grouped into spontaneous vaginal delivery, caesarean section and instrumental vaginal delivery.
**Ethical approval**

According to NHS Health Research Authority (HRA) definitions (22), this study was not considered as research and therefore ethical approval from the NHS HRA or the local ethics board was not required.

**Results**

Our initial search yielded 16840 heart rate readings from 11401 women. The exclusion criteria for sepsis, haemorrhage and anaemia removed 9207 readings from 6237 women, leaving 7633 heart rate readings from 5164 women. 6 women had erroneous heart rate readings (ranging between 12-18 bpm) with duplicate readings recorded at the same time of values which would be expected. These low values were postulated to be input error by the user recording heart rate and therefore excluded, thus leaving 7627 readings from 5164 women.

**Heart rate at time intervals following delivery (6, 12, 24 and 48 hours)**

Heart rate was normally distributed at all four time points (Figure 1A-D). The mean heart rate ($\mu$) was 83.6 beats per minute (bpm) at 6 hours, 84.5 at 12 hours, 85.4 at 24 hours and 84.3 at 48 hours (Table 1).

The mean heart rate at 6 hours (83.6) was significantly different to both 12 (84.5, $p=0.041$) and 24 hours (85.4, $p<0.001$).

When mean + 2 standard deviations ($\mu+2\text{SD}$) is taken as the upper threshold for the normal range, the respective values are 108.2, 109.4, 110.4 and 109.7 at 6, 12, 24 and 48 hours after delivery.

When mean + 3 standard deviations ($\mu+3\text{SD}$) is used, the respective values are 120.6, 121.9, 123.0 and 122.4 bpm.

The postpartum time interval cohorts characteristics were compared (Table 2). Significant differences were found in the method of delivery; with a lower proportion (45.0%) of non-
instrumental vaginal deliveries in women at 48 hours (p=0.020) and discharge haemoglobin; with women at 48 hours having lower discharge haemoglobin (112 g/L) than 6 (114 g/L) and 12 hours (112 g/L) (p=0.009).

For the following analyses data across all time points were grouped together.

**BMI**

Data for BMI were missing for 191 readings from the 7627, thus leaving 7436 readings across all time intervals postpartum (6, 12, 24 & 48 hours).

The mean heart rate was 83.2 bpm in underweight, 83.2 ideal weight, 84.9 in overweight, 86.3 in obese I, 85.1 in obese II and 87.9 in obese III women (Table 3) (p<0.001, observed power =1.000).

There was a significant direct correlation between heart rate and BMI of 0.097 (p<0.001).

**Age**

The mean heart rate was 86.7 in women less than 20 years old, 85.1 in 20-29 years old, 83.6 in 30-39 years old and 84.4 in ≥40 years old (p<0.001, observed power =1.000) (Table 3).

There was a significant inverse correlation between heart rate and age of -0.079 (P<0.001).

**Puerperal blood loss**

Mean heart rate was 85.1 (≤100 ml), 82.6 (100-199), 83.4 (200-299), 83.9 (300-399), 84.7 (400-499), 86.3 (500-599), 84.8 (600-699), 85.6 (700-799), 86.1 (800-899) and 85.8 (900-999), with significant variation (Table 3) (p<0.001, observed power =1.000). There was no correlation between heart rate and blood loss.
**Discharge haemoglobin**

2556 of the heart rate readings had missing entries for discharge haemoglobin. It was not hospital policy to take a postpartum haemoglobin measurement unless indicated. This meant 5071 heart rate readings were analysed for an association with discharge haemoglobin.

There was a significant inverse correlation between heart rate and discharge haemoglobin of -.031 (p=0.027), however women with anaemia or severe postpartum haemorrhage were excluded.

**Method of delivery**

Mean heart rate was highest in women who delivered by an instrumental delivery (85.5) and lowest in women who delivered by spontaneous vaginal delivery (83.9) (p=0.002, observed power =0.975) (Table 3).

The mean heart rate for the spontaneous vaginal deliveries was significantly less than Caesarean section (p=0.024) and instrumental vaginal deliveries (p<0.001). This may reflect a relationship with blood loss, demonstrated by a significantly higher mean blood loss in Caesarean section (285 ml) than both instrumental vaginal delivery (230 ml) and non-instrumental vaginal delivery (193 ml) respectively (p<0.001).

**Length of stay**

There was no significant correlation between heart rate and length of stay.

**Comments**

This large study describes the distribution of heart rate in the first 48 hours postpartum, in women with no evidence of sepsis, haemorrhage or anaemia. The normal range upper limits (mean + 2SDs and mean + 3 SDs) have also been described. Given previous literature has only described the changes in postpartum maternal heart rate weeks after delivery, this is a novel observation.
Although statistically significant differences in heart rate have been shown between various time points (at 6, 12, 24 and 48 hours) post-delivery, these differences are small and not clinically meaningful.

The first 48 hours after delivery represents a time when significant maternal morbidity and mortality can occur. Women with tachycardia not associated with sepsis, haemorrhage or anaemia (unexplained tachycardia) should be investigated for other causes such as occult bleeding, pulmonary embolism and cardiac pathology as these can all cause serious maternal morbidity or death. Conversely, unnecessary investigations can be avoided with a heart rate below the thresholds described and in the absence of other signs/symptoms.

In the cohort of women in hospital at 48 hours, fewer had a normal vaginal delivery (45.0% compared to 52.0%, 54.4% and 52.0% at 6, 12 and 24 hours respectively). Whilst this could influence the heart rate distribution, it is likely that in most maternity units women who have instrumental deliveries or caesarean sections stay in hospital longer than those having non-instrumental vaginal deliveries. Our cohort is therefore likely to represent clinical practice in the UK, and our findings are therefore relevant to clinicians working in UK NHS hospitals.

Our data showed a positive correlation between BMI and heart rate, however there was only 4 bpm difference between the lowest (underweight) and highest (obese III) groups. Thus, with the greater complication risk during pregnancy associated with maternal obesity, obese women with unexplained tachycardia should still be investigated at the same thresholds as non-obese women (23-25). This is pertinent given the association obesity has with maternal mortality and cardiovascular disease (26, 27).

The significantly lower heart rate in those having normal vaginal deliveries, compared to both Caesarean sections and instrumental deliveries respectively, may represent a reduced blood loss (28). However, no correlation was found between blood loss and heart rate although a significant
correlation was found with discharge haemoglobin. This may reflect two different physiological processes: 1) Peripartum blood loss is an acute change resulting in a fall in circulating volume. By 6 hours, euvoelaemia would have been restored and therefore no effect on heart rate was observed. Furthermore, no account was taken in this study of the use of intravenous fluids in labour, which may have further compensated for blood volume loss. As Caesarean section deliveries are associated with higher blood loss, women undergoing Caesarean section are more likely to have intravenous fluid therapy. 2) Tachycardia in response to anaemia reflects a reduced oxygen carrying capacity (29, 30). There was an increase in maternal heart rate associated with discharge haemoglobin at each time point studied. Raised maternal heart rate at 6, 12, 24 and 48 hours may be more reflective of anaemia. Data on antenatal haemoglobin were not included in the analysis, and therefore it is not possible to say whether this change reflects a response to a fall in haemoglobin, or anaemia per se which may have been longstanding.

Tools which aid early detection of deterioration of patients, such as early warning scores (EWS), have been widely adopted. Physiological differences in pregnancy and postpartum necessitate a specific obstetric EWS(31). Despite development of several modified early obstetric warning scores (MEOWS); including the questionnaire based model from Swanton et al.(16) and the statistical based from Carle et al. (17), there remains no consensus (32, 33) and a postpartum specific EWS has yet been devised. Furthermore, the existing MEOWS have their limitations, with Swanton et al. relying upon expert opinion rather than quantitative data and Carle et al. using an Intensive Treatment Unit cohort; thus likely overestimating the prevalence of both significant pathology and the requirement for multi-organ support compared to an unselected cohort, as used in this study. The results from this study can be used to form the basis for further work to create a postpartum EWS.

Study Strengths

This retrospective cross-sectional analysis is the first to describe maternal heart rate in the early postpartum period.
This large dataset enabled identification of significant differences in heart rate between several subgroups of postpartum women. Data was sourced retrospectively from initial clinical vital signs recordings as per routine postpartum care for women delivering in our unit. This removed potential bias from data collection, sample selection and the environment in which the readings were taken, strengthening the study's conclusions transferability.

The data from the excluded cases (Table 4), where women had sepsis or anaemia, revealed that the increase in heart rate was greater with time than in the ‘normal’ cohort included in the study. Furthermore, the mean heart rates of the excluded cohorts were greater than the included cohort at each given time interval. These observations were expected and justified our decision to exclude such cases in order to make the data presented in this study representative of a normal population.

**Study Limitations**

Although the study provides a sound statistical basis for postpartum EWS development, it has not yet been correlated with outcome measures i.e. morbidity or mortality. Therefore despite being able to suggest thresholds for abnormality, this study does not help predict the likelihood of underlying pathology if a tachycardia is detected. Even with a cohort this size, this is not possible since serious maternal morbidity and mortality are rare outcomes.

Each heart rate reading was treated separately, therefore any women with multiple readings would have multiple entries (maximum of 4) for the independent variables (e.g. BMI, age, delivery method etc.) and thus would be over represented within that variable when combining the postpartum heart rate data for all time intervals (6, 12, 24 and 48 hours). Given the significantly lower rate of non-instrumental vaginal deliveries at 48 hours, this may have led to women who had Caesarean section and instrumental vaginal deliveries being overrepresented.
Whilst the study’s dataset size is a strength, it meant statistically significant differences between groups were identified despite small margins. Some of these differences are unlikely to be clinically significant.

Data were collected retrospectively, thus with no standard way of measuring heart rate identified; both electronic and manual recordings were included. However, this reflects past and current practice within the unit.

Use of medication at the time the heart rates were recorded was not considered in this study. Negatively chronotropic drugs such as beta blockers, commonly prescribed to postpartum women with hypertension (34, 35), could lower heart rate and thus skew the data.

All women in the study came from one tertiary centre for obstetrics, where women with pre-existing medical conditions may be overrepresented. Furthermore, this study looked at heart rates up to 48 hours postpartum; the cohort studied at 48 hours in particular, may include a greater proportion of women with medical problems as healthy women with healthy babies may have already been discharged.

Conclusion

We have reported heart rate data at 6, 12, 24 and 48 hours postpartum. There is a statistically, but not clinically, relevant difference in maternal heart rate between these time points. We have also suggested upper thresholds of normality at which further clinical investigation should occur.

These findings provide a basis for heart rate parameters to be created for a postpartum EWS. This will aid in the early recognition of women who may develop critical illness or cardiovascular pathology in the postpartum period and provide an opportunity for earlier investigation and intervention. Furthermore, the findings will also support clinicians in avoiding inappropriate investigation, therefore saving resources, facilitating earlier discharge and reducing anxiety for women.
Future work in this area is still required in order to increase the evidence base on postpartum heart rates in other cohorts and to incorporate correlation with poor maternal outcomes into any future postpartum EWS.

**Acknowledgements**

I would like to thank Thomas Drury at the Central Manchester Hospital Trust electronic warehouse, for conducting the data search and providing the data.

**Funding**

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References

22. HRA. Defining research: your guide to help decide whether your research requires review from a Research Ethics Committee. NHS Health Research Authority; 2013.
Disclosure of interests

There are no competing interests from any of the authors.