Discharge Age and Weight for Very Preterm Infants in Six Countries: 2012 to 2020

Erika M. Edwards[1,2,3], Lucy T. Greenberg[1,3], Jeffrey D. Horbar[1,2], Luigi Gagliardi[4], Mark Adams[5], Angelika Berger[6], Sara Leitao[7], Karen Luyt[8], Danielle E.Y. Ehret[1,2], Jeannette A. Rogowski[9]

1. Vermont Oxford Network, Burlington, VT, USA

2. Department of Pediatrics, Robert Larner, MD, College of Medicine, University of Vermont, Burlington, VT, USA

3. Department of Mathematics and Statistics, College of Engineering and Mathematical Sciences, University of Vermont, Burlington, VT, USA

4. Division of Neonatology and Pediatrics, Ospedale Versilia, Viareggio, AUSL Toscana Nord Ovest, Pisa, Italy

5. Newborn Research, Department of Neonatology, University and University Hospital Zurich, Zurich, Switzerland

6. Department of Pediatrics, Division of Neonatology, Pediatric Intensive Care and Neuropediatrics, Comprehensive Center for Pediatrics, Medical University Vienna, Vienna, Austria

7. National Perinatal Epidemiology Centre, Department of Obstetrics and Gynecology, Cork University College Cork, Cork, Ireland

8. Bristol Medical School, University of Bristol, Bristol, United Kingdom

9. Department of Health Policy and Administration, The Pennsylvania State University, State College, PA, USA

Corresponding Author: Erika M. Edwards, PhD, MPH, Director of Data Science, Vermont Oxford Network, Burlington, VT 05401, USA, eedwards@vtoxford.org

Short Title: Discharge Age and Weight in Six Countries

Tables: 3

Figures: 4

Word count: 2223

Keywords: neonatology; preterm infants; length of stay; utilization

Abstract

Background: Postmenstrual age for surviving infants without congenital anomalies born at 24 to 29 weeks' gestational age from 2005 to 2018 in the United States increased 8 days, discharge weight increased 316 grams, and median discharge weight z-score increased 0.19 standard units. We asked whether increases were observed in other countries.

Methods: We evaluated postmenstrual age, weight, and weight z-score at discharge of surviving infants without congenital anomalies born at 24 to 29 weeks' gestational age admitted to Vermont Oxford Network member hospitals in Austria, Ireland, Italy, Switzerland, the United Kingdom, and the United States from 2012 to 2020.

Results: After adjustment, the median postmenstrual age at discharge increased significantly in Austria (3.6 days, 99% CI [1.0, 6.3]), Italy (4.0 days [2.3, 5.6]), and the United States (5.4 days [5.0, 5.8]). Median discharge weight increased significantly in Austria (181 grams, 99% CI [95, 267]), Ireland (234 [143, 325]), Italy (133 [83, 182]), and the United States (207 [194, 220]). Median discharge weight z-score increased in Ireland (0.24 standard units, 99% CI [0.12, 0.36]) and the United States (0.15 [0.13, 0.16]). Discharge on human milk increased in Italy, Switzerland, and the U.K. while going home on cardiorespiratory monitors decreased in Austria, Ireland and U.S. and going home on oxygen decreased in Ireland.

Conclusions: In this international cohort of neonatal intensive care units, postmenstrual discharge age and weight increased in some, but not all, countries. Processes of care at discharge did not change in conjunction with age and weight increases.

Introduction

A recent study found that postmenstrual age at discharge increased 8 days, discharge weight increased 316 grams, and median discharge weight z-score increased 0.19 standard units, among surviving infants without congenital anomalies who were born at 24 to 29 weeks' gestational age from 2005 to 2018 and admitted to a Vermont Oxford Network member hospital in the United States (U.S.).[1] The authors observed increases within every week of gestational age with and without adjustment for infant characteristics. The increases in discharge age occurred despite morbidity decreases[2] and care process improvements[3] that would suggest that infants should be discharged sooner.

One hypothesis for the increase in discharge age was care process improvements such as resolving apnea of prematurity or establishing breastfeeding prior to discharge. Another hypothesis was misaligned financial incentives in the U.S. healthcare system that may encourage hospitals to keep infants hospitalized, although an accompanying commentary observed that financial incentives were stable during the study period, suggesting that probably was not the cause.[4]

This study replicates the original discharge age and weight methodology in Austria, Ireland, Italy, Switzerland, and the United Kingdom (U.K.) to ascertain if discharge age and weight increased in these countries. The idea stemmed from unpublished data in Italy where similar increases were observed. The goals of healthcare's quintuple aim are to improve population health, enhance care, reduce costs, reduce provider burnout, and advance health equity.[5] Understanding whether postmenstrual discharge age and weight increased in countries other than the United States can help identify the role of neonatal care management and what could or should be done to help neonatology enhance care, reduce costs, and improve population health.

Methods

Vermont Oxford Network (VON) is a voluntary worldwide community of practice with members in 38 countries dedicated to improving the quality, safety, and value of newborn care through a coordinated program of data-driven quality improvement, education, and research. The University of Vermont institutional review board determined that the use of data from the VON Research Repository for this analysis was not human subjects research.

VON member hospitals in Austria, Ireland, Italy, Switzerland, the U.K., and the U.S. contributed data on infants 401 to 1500 grams or 22 0/7 to 29 6/7 weeks' gestational age at birth who were inborn or transferred to the reporting hospital within 28 days from birth from January 1, 2012 to December 31, 2020. These countries were chosen because all or many NICUs participate in VON. The study started in 2012 due to adoption of a diagnosis-based group hospital payment system in Switzerland.[6] All data were collected by local staff using standardized definitions[7] which facilitated comparisons across countries.

All liveborn infants born from 24 0/7 to 29 6/7 weeks' gestation without congenital anomalies who survived to discharge home were included. Postmenstrual age at discharge was calculated as gestational age at birth in days plus total length of stay in days. Transferred infants' length of stay was tracked by the reporting hospitals until ultimate disposition. Discharge weight for infants was assessed for infants initially discharged home only because weight at ultimate disposition for transferred infants was not available. Z-scores for weight at birth and discharge up to 50 weeks postmenstrual age were calculated using the Fenton growth chart.[8] Z-scores for discharge after 50 weeks' postmenstrual age were calculated using the WHO Child Growth Standards with corrected age.[9] The proportions of infants who were discharged home on oxygen, on cardiorespiratory monitors, or on any human milk were assessed to evaluate clinical factors that may influence discharge age.

The median postmenstrual age, weight, and z-score for weight at discharge were calculated using bootstrapping to estimate a 99% confidence interval for each country and year. Quantile regression adjusted for infant characteristics (gestational age in weeks, birth weight z-score, sex, multiple birth, one minute Apgar score, inborn/outborn) was used to estimate differences over time in median age, weight, and discharge weight z-score in each country. Logistic regression models with linear time trend were used to assess the significance of changes in discharges on human milk, on oxygen, and on cardiorespiratory monitors over the time period. All analyses used significance level $\alpha=0.01$. Sensitivity analyses were performed to assess the potential impact of the SARS-COV-2 pandemic by removing 2020.

Hospital characteristics were obtained from the VON annual member survey. Using responses to whether the hospital was required to transfer infants for assisted ventilation or whether one of eight surgeries was performed at the hospital (omphalocele repair, ventriculoperitoneal shunt, tracheoesophageal fistula and/or esophageal atresia repair, bowel resection and/or reanastomosis, meningomyelocele repair, PDA ligation, cardiac catheterization, or cardiac surgery requiring bypass), hospitals were divided into four groups: ventilation restrictions, no surgery; no ventilation restrictions, no surgery; no ventilation restrictions, surgery except cardiac requiring bypass; and no ventilation restrictions, cardiac surgery requiring bypass. Teaching hospitals included those in which pediatric residents, neonatology fellows, or other residents participated in direct patient care in the NICU.

Results

From 2012 to 2020, 967 hospitals contributed data (Austria (n=11), Ireland (n=20), Italy (n=87), Switzerland (n=9), U.K. (n=38), U.S. (n=802)) of which 13% were hospitals with ventilation restrictions and without surgical services, 37% were without restrictions on ventilation that did not do surgery, 36% were without restrictions on ventilation that performed surgery except cardiac surgery requiring bypass, and 14% were without restrictions on ventilation that performed cardiac surgery requiring bypass. Hospital data by country are provided in Supplemental Table 1.

Overall, 232,203 infants were evaluated. From 2012 to 2020, the median postmenstrual age at discharge ranged from 37 weeks, 6 days (Ireland) to 38 weeks, 5 days (U.S.). The median discharge weight ranged from 2400g (Italy) to 2900g (Switzerland), and the median discharge weight z-score ranged from -1.5 (Italy) to -0.7 (Ireland). Observed medians over time are shown in Figure 1 and Table 2, and infant characteristics in Table 1.

After adjustment, the median postmenstrual age at discharge increased at hospitals in Austria (3.6 days, 99% CI [1.0, 6.3]), Italy (4.0 days, 99% CI [2.3, 5.6]), and the U.S. (5.4 days, 99% CI [5.0, 5.8]). Median postmenstrual age at discharge increased at hospitals in Ireland and decreased at hospitals in Switzerland and the U.K., although not significantly (Table 2 and Figure 2). Median postmenstrual age at discharge decreased with increasing gestational age at birth (Figure 3).

Median discharge weight increased at hospitals in Austria (181 grams, 99% CI [95, 267]), Ireland (234 grams, 99% CI [143, 325]), Italy (133 grams, 99% CI [83, 182]), and the U.S. (207 grams, 99% CI [194, 220]). Median discharge weight decreased at hospitals in Switzerland and increased in the U.K., although not significantly (Table 2 and Figure 2). Median weight at discharge decreased with increasing gestational age at birth (Figure 3).

Median discharge weight z-score increased at hospitals in Ireland (0.24 standard units, 99% CI [0.12, 0.36]) and the U.S. (0.15 standard units, 99% CI [0.13, 0.16]). Median discharge weight z-score increased at hospitals in Austria, Italy, and the U.K. and decreased in Switzerland, although not significantly (Table 2 and Figure 2). Median discharge weight z-score generally increased with gestational age at birth (Figure 3).

From 2012 to 2020, the percentage of infants discharged on human milk increased in Italy (61% to 75%), Switzerland (70% to 76%), and the U.K. (43% to 62%). Hospitals in Austria (50% to 32%), Ireland (17% to 16%), and U.S. (28% to 18%) decreased the percentage of infants going home on a cardiorespiratory monitor. Hospitals in Ireland decreased (7% to 3%) rates of oxygen at discharge (Figure 4).

A sensitivity analysis excluding 2020 did not change the results (Supplemental Figure 1). The proportion of extremely preterm infants born from 24 to 26 weeks' gestational age and the proportion who survived did not change over time (Supplemental Figure 2).

Discussion

In this international cohort, postmenstrual age, weight, and weight z-score at discharge increased significantly in some, but not all, countries. Median postmenstrual age at discharge increased in three of six countries (Austria, Italy, and the U.S.), median weight at discharge in four (Austria, Ireland, Italy, and the U.S.), and median discharge weight z-score in two (Ireland and the U.S.). While the difference in postmenstrual age at discharge between the six countries was only six days on average (37 6/7 to 38 5/7), there was more variation in discharge weights

(2400 grams to 2900 grams on average) which likely reflects differences in feeding or nutritional practices.

We explored discharge on oxygen, cardiorespiratory monitors, and human milk to explain the increases in postmenstrual age at discharge. The proportion of infants discharged on cardiorespiratory monitors decreased in Austria and the U.S. without a decrease in oxygen at discharge. This finding suggests that use of monitors with home oxygen for bronchopulmonary dysplasia was stable while use of monitors for apnea decreased, perhaps due to more emphasis on apnea management before initial discharge or due to more strict indications for the need to discharge an infant on a monitor. However, understanding the relationship between the use of cardiorespiratory monitors and length of stay requires more detailed information than is available in the VON database. The proportion of infants discharged home on human milk increased significantly in Italy, suggesting more time or effort spent establishing breastfeeding. There is little correspondence at the country level between the increases in postmenstrual age and weight at discharge and changes in these factors. Whether these factors definitively influenced postmenstrual age at discharge is unknown. There is marked variation in clinical practices related to apnea monitoring, oxygen supplementation, postnatal steroids for chronic lung disease, and breastfeeding within and among countries, all of which may affect length of NICU stay, growth at discharge, and readmission rates. Future research should address the impact of these practices on the outcomes we have assessed. Of particular importance is the use of human milk which should be available for all preterm infants.

A previous study of length of stay among survivors born from 24 to 28 completed weeks gestational age in 2014 to 2016 across 10 countries including Switzerland and the U.K. found that median length of stay varied from 75 days in Finland to 107 days in Israel.[10] Median length of stay was 84 days (IQR: 69, 103) in Switzerland and 82 days (IQR: 66, 103) in the U.K. A study comparing hospital length of stay for infants born 22 to 31 completed weeks gestational age in 10 European regions showed no change across regions from 2003 to 2011/2012 after adjustment, but with wide variation by country.[11] A systematic review of factors that increase length of stay in a neonatal unit found that organizational factors within a geographic region, such as level of care, may influence length of stay, but the study did not mention factors across geographic regions, such as healthcare financing systems.[12] Organizational factors such as management of neonatal intensive care units in Italy has also been found to be associated with outcomes.[13] However, in a large integrated health system in southern California, NICU patient days decreased from 2010 to 2018, although most of the change occurred among infants with higher birth weights and gestational ages.[14] The authors of that study suggest that the hospital system's financial structure, which is population-based rather than fee-for-service, had financial incentives to decrease NICU admissions and lengths of stay. The role of financial incentives in the increases observed in the current study is complex because healthcare financing mechanisms differ at the federal, state, and even local level. Still, increases in postmenstrual age at discharge were observed regardless of financing systems.

This study's limitations include lack of information on discharge policies at the unit or country level. While in Austria, Ireland, Italy, Switzerland, and the United States, all or nearly all NICUs routinely caring for the study population participate in VON, not all NICUs are VON members and the results may be different for non-members. Membership by country varies by NICU level; higher-level NICUs are more likely to be represented in VON except in the U.K., which has a highly regionalized care structure with more non-tertiary level units than tertiary units. We do not know readmission rates, and we do not have enough information to determine causal mechanisms. There could be unmeasured differences in survivors contributing to our findings. Finally, 2020 includes part of the SARS-CoV-2 pandemic, which influenced NICU admissions and discharges[15,16]; however, a sensitivity analysis excluding 2020 did not change our results.

What do these findings mean for families? In Austria, Italy, and the U.S., age at discharge increased, meaning that infants are spending more time away from their homes today than in previous years. The balance between longer stays and readmission is the biggest unknown, although a U.S. study found that infants with shorter initial NICU lengths of stay had higher readmission rates.[17] Readmission rates may be easier to measure in countries with social insurance systems; readmission deserves further inquiry given the increases in discharge age. Infants in Austria and the U.S. are going home with less monitoring, which should benefit families. Discharge weight increased in Austria, Italy, and the U.S. too, but discharge weight z-scores increased only in the U.S., suggesting that increases in discharge weight in Austria and Italy were due to increases in discharge age and not in gains made against gestational age standards (although experts are uncertain about the usefulness of z-scores).[18] In Switzerland and the U.K., postmenstrual age at discharge did not increase significantly; however, discharge weight and discharge weight z-score also did not increase, although discharge weight and discharge weight z-score were among the highest in Switzerland during the entire period despite the highest proportion of infants small for gestational age at birth. The Irish units may have solved the value equation for families: the lowest median postmenstrual age at discharge and increases in discharge weight, discharge weight z-score, and the proportion discharged on human milk, without significant increases in discharge age.

Conclusions

In this international cohort of NICUs, postmenstrual age, weight, and weight z-score at discharge age increased in some, but not all, countries. Despite the study's limitations, we contribute to the growing literature about NICU length of stay. Enhancing care, reducing costs, and advancing health equity, three parts of healthcare's quintuple aim,[5] are essential to improve the value of care for families. Apnea monitoring practices, discharge care practices, and readmission rates deserve deeper examination as the field continues to evaluate the impact of these increases.

Acknowledgements: We are indebted to our colleagues who submit data to Vermont Oxford Network on behalf of infants and their families. Thank you to the Neonatal Intensive Care Outcomes Research and Evaluation (NICORE) in the Republic of Ireland, the Italian Neonatal Network, and SwissNeoNet for facilitating membership and data submission on behalf of hospitals in those countries. The list of hospitals contributing data to this study are in Supplemental Table 2.

Conflict of Interest: Jeffrey Horbar is Chief Executive Officer, President, and Chief Scientific Officer of Vermont Oxford Network, and an unpaid member of the Vermont Oxford Network Board of Trustees. Erika Edwards receives salary support from Vermont Oxford Network. The other authors have no conflicts of interest to disclose.

Informed Consent: The University of Vermont institutional review board determined that the use of data from the VON Research Repository for this analysis was not human subjects research

Ethics: The University of Vermont institutional review board determined that the use of data from the VON Research Repository for this analysis was not human subjects research.

Ethical Approval: The University of Vermont institutional review board determined that the use of data from the VON Research Repository for this analysis was not human subjects research.

Ethical Review Board: The University of Vermont institutional review board

Funding Sources: None

Contributors' Statement: Dr. Edwards conceptualized and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript. Ms. Greenberg conceptualized and designed the study, carried out the data analyses, and reviewed and revised the manuscript. Drs. Horbar, Gagliardi, Adams, Berger, Leitao, Luyt, Ehret, and Rogowski conceptualized and designed the study and reviewed and revised the manuscript.

Data Availability: The data that support the findings of this study are not publicly available due to data sharing agreements with member hospitals. Individuals at Vermont Oxford Network member hospitals seeking to use data can contact Erika Edwards.

References

1 Edwards EM, Greenberg LT, Ehret DEY, Lorch SA, Horbar JD. Discharge age and weight for very preterm infants: 2005-2018. Pediatrics. 2021 Feb;147(2). DOI: 10.1542/peds.2020-016006

2 Horbar JD, Edwards EM, Greenberg LT, Morrow KA, Soll RF, Buus-Frank ME, et al. Variation in performance of neonatal intensive care units in the United States. JAMA Pediatrics. 2017;171(3):e164396.

3 Soll RF, Edwards EM, Badger GJ, Kenny MJ, Morrow KA, Buzas JS, et al. Obstetric and neonatal care practices for infants 501 to 1500 g from 2000 to 2009. Pediatrics. 2013 Aug;132(2):222–8.

4 Arnold C, Davis AS. Increasing length of stay in the NICU for premature newborns: Good or bad? Pediatrics. 2021 Feb;147(2). DOI: 10.1542/peds.2020-032748

5 Nundy S, Cooper LA, Mate KS. The Quintuple Aim for Health Care Improvement: A New Imperative to Advance Health Equity. JAMA. 2022 Jan DOI: 10.1001/jama.2021.25181

6 Koné I, Maria Zimmermann B, Nordström K, Simone Elger B, Wangmo T. A scoping review of empirical evidence on the impacts of the DRG introduction in Germany and Switzerland. Int J Health Plann Mgmt. 2019 Jan;34(1):56–70.

7 Vermont Oxford Network. Manual of Operations, Part 2 for Infants Born in 2020. Data Definitions and Infant Data Forms. Burlington, Vermont: Vermont Oxford Network; 2019.

8 Fenton TR, Kim JH. A systematic review and meta-analysis to revise the Fenton growth chart for preterm infants. BMC Pediatr. 2013 Apr;13:59.

9 WHO Multicentre Growth Reference Study Group. Length/height-for-age, weight-for-age, weight-for-length, weight-for-height, and body mass index-for-age: Methods and development. Geneva, Switzerland: World Health Organization; 2006.

10 Seaton SE, Draper ES, Adams M, Kusuda S, Håkansson S, Helenius K, et al. Variations in neonatal length of stay of babies born extremely preterm: An international comparison between iNeo Networks. The Journal of Pediatrics. 2021 Jun;233:26-32.e6.

11 Maier RF, Blondel B, Piedvache A, Misselwitz B, Petrou S, Van Reempts P, et al. Duration and time trends in hospital stay for very preterm infants differ across European regions. Pediatric Critical Care Medicine. 2018 Dec;19(12):1153–61.

12 Seaton SE, Barker L, Jenkins D, Draper ES, Abrams KR, Manktelow BN. What factors predict length of stay in a neonatal unit: a systematic review. BMJ Open. 2016 Oct;6(10). DOI: 10.1136/bmjopen-2015-010466

13 Fanelli S, Bellù R, Zangrandi A, Gagliardi L, Zanini R. Managerial features and outcome in neonatal intensive care units: results from a cluster analysis. BMC Health Serv Res. 2020 Dec;20(1):957.

14 Braun D, Braun E, Chiu V, Burgos AE, Gupta M, Volodarskiy M, et al. Trends in Neonatal Intensive Care Unit Utilization in a Large Integrated Health Care System. JAMA Network Open. 2020 Jun;3(6):e205239.

15 Greenbury SF, Longford N, Ougham K, Angelini ED, Battersby C, Uthaya S, et al. Changes in neonatal admissions, care processes and outcomes in England and Wales during the COVID-19 pandemic: a whole population cohort study. BMJ Open. 2021 Oct;11(10):e054410.

16 Rasmussen MI, Hansen ML, Pichler G, Dempsey E, Pellicer A, EL-Khuffash A, et al. Extremely Preterm Infant Admissions Within the SafeBoosC-III Consortium During the COVID-19 Lockdown. Front Pediatr. 2021 Jul;9:647880.

17 Bernardo J, Keiser A, Aucott S, Yanek LR, Johnson CT, Donohue P. Early Readmission following NICU Discharges among a National Sample: Associated Factors and Spending. Am J Perinatol. 2021 Oct;s-0041-1736286.

18 Fenton TR, Dai S, Lalari V, Alshaikh B. Neonatal and Preterm Infant Growth Assessment. Clinics in Perinatology. 2022 Jun;49(2):295–311.

Figure Legends

Figure 1: Observed medians for postmenstrual age at discharge (red), discharge weights (green), and discharge weight z-scores (blue) with 99% confidence intervals, 2012 to 2020, by country.

Figure 2: Changes in postmenstrual age at discharge, discharge weights, and discharge weight z-scores with 99% confidence intervals, 2012 to 2020, by country, adjusted for gestational age in weeks, birth weight z-score, sex, multiple birth, one minute Apgar score, and inborn/outborn status.

Figure 3: Median postmenstrual age at discharge (red), discharge weights (green), and discharge weight z-scores (blue) with 99% confidence intervals by gestational age at birth, by country.

Figure 4: Observed rates of infants discharged on human milk (red), cardiorespiratory monitor (green), and oxygen (blue), 2012 to 2020, by country.