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Management and outcomes of periviable infants in Slovenia: a decade of experience

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Abstract

Objectives: To determine rates of active approach, mortality, and morbidity for periviable infants at level 3 maternity hospital between 2013 and 2022.

Methods: Single center retrospective cohort study including mothers and their liveborn infants at gestational age from 22^{+0} weeks to 24^{+6} weeks during a ten-year period. Clinical data regarding pregnancy, delivery, neonatal mortality, and morbidity were collected from the Vermont Oxford Network (VON) database.

Results: A total of 185 liveborn infants with gestational age (GA) from 22^{+0} to 24^{+6} weeks were included. A high proportion of the most immature infants were not treated actively (92 % infants born at 22 weeks of GA died in delivery room). Survival rates according to GA were 4 % (22 weeks), 40.7 % (23 weeks), and 65.1 % (24 weeks). Of the infants admitted to the neonatal intensive care unit (n=142), 25.3 % had severe intraventricular hemorrhage (grade III or IV) or periventricular leukomalacia, 13.4 % underwent abdominal surgery (due to necrotizing enterocolitis), and 17.6 % required laser treatment for retinopathy of prematurity. Supplemental oxygen at 36 weeks postmenstrual age was required by 40.8 % infants.

Conclusions: At our center, which cares for more than 90 % of periviable newborns born in Slovenia, we achieved comparable survival and morbidity outcomes for actively approached liveborn periviable infants compared to those from developed countries reported in the literature. In the future, we aim to implement active antenatal care for pregnant women and infants born after completed 22 weeks of gestation and monitor the long-term outcomes of all infants born at the limit of viability.

Keywords: limit of viability; extremely preterm infant; periviability

Introduction

Definition of viability has had numerous interpretations and remains mainly, but not exclusively based on gestational age (GA) [1]. It has been defined as infants' ability to survive independently outside the womb, as a stage of maturation of central nervous system that poses a premise of conscience, as achieved lung maturity, or as the gestational age where the fetus is sufficiently mature to survive the neonatal period with available medical support [2–5]. Due to vast differences in available healthcare globally, clinically commonly used criterion for viability is the gestational age at which half of delivered infants survive with the available medical support, under the precondition that the mother received active antenatal care. For Slovenia, the limit is 24 weeks of gestation [6, 7].

The possibility of extrauterine survival is biologically determined by the ability of lungs to utilize air, which occurs roughly between 22 and 25 weeks' gestation, also referred to as periviability [3]. There is a prognostic uncertainty for periviable infants also due to large variation in resources and guidelines regarding antenatal care of women anticipating delivery at a periviable gestation and active treatment for infants [4, 8, 9]. Effective antenatal practices such as antenatal corticosteroids, magnesium sulfate for tocolysis and neuroprotection, antibiotic prophylaxis, and transport *in utero* to specialized centers increase the probability of successful neonatal intervention [9–12]. Significantly higher survival rates are achieved in countries with centralized care and a uniformed active care approach, such as Sweden, with 40 % survival rate for infants born at 22 weeks' gestation [10, 12, 13]. Their guidelines from 2016 consider life support for all infants born from 22^{+0} weeks of gestation, which differs from standard approach guidelines of otherwise comparable neighboring Scandinavian countries. Compared to Norway and Denmark, Sweden has had higher survival rates not only for GA of 22 and 23 weeks, but for all

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periviable gestations, according to data between 2018 and 2022 [13]. Additionally, other centers providing care to extremely low gestation infants have also shown improved outcomes for more mature infants [14].

Despite remaining differences in guidelines worldwide, a shift towards more active management for the tinniest infants is being recognized. A summary of survival rates from different tertiary center collaborations published in 2010 showed 1–15 % survival at 22 weeks, 8–33 % at 23 weeks and 26–51 % at 24 weeks of gestation [4]. Between 2007 and 2019, data from USA neonatal intensive care units (NICUs) reporting to Vermont Oxford Network (VON) showed a marked increase in rates of active management (from 26 to 58 %) and survival (from 5 to 17 %) for infants born at 22 weeks of gestation [15]. The most recent published data from VON encompassing survival and morbidity rates for 22,953 periviable infants born between 2020 and 2022 showed a further increase in active care (from 61.6 to 73.7 %) and survival (24.9 %) at 22 weeks, with survival rates to 82 % at 25 weeks. However, survival without severe complications remained low (from 6.3 % at 22 weeks to 43.2 % at 25 weeks) [16].

Our level III NICU at the Department of Perinatology–Maternity hospital Ljubljana, Slovenia, is a tertiary center which provides specialized care for mothers and periviable infants with roughly 100 - 150 admissions of very low birth weight infants per year. Due to the transfer of pregnant women with the threat of extremely premature birth (transport *in utero*, in Slovenia established in 1986) from all secondary level maternity hospitals, more than 90 % of Slovenian newborns with a gestation of less than 26 weeks are delivered in it. According to our guidelines, active management is initiated for infants born at 24 weeks and 0 days GA, with an expected survival rate >65 % and rates of long-term neurological complications such as cerebral palsy less than 10 % [7]. Our approach to infants born at <24 weeks has been so far selective treatment based on initial clinical evaluation of the infant and discussion of parental wishes and expectations, mostly based on the decision of the on-call neonatologist. However, centers using an active approach to treating infants born at the limit of viability have reported comparable mortality and morbidity outcomes even for infants born between 22 and 24 weeks' GA [17]. Mortality and morbidity outcomes for infants born between 22^{+0} and 24^{+6} weeks in Slovenia have not been investigated previously. Further, despite growing number of publications reporting survival and morbidity rates at periviable gestations, it remains unclear whether adopting a uniform active approach would result in higher rates of morbidity free survival, especially for infants born at 22 weeks of gestation. The aim of our study was to review our own data for infants born from 22^{+0} to 24^{+6} weeks GA over a ten-year period at Maternity hospital Ljubljana, University Medical Centre Ljubljana, Slovenia.

Methods

Vermont Oxford Network (VON) is a voluntary, nonprofit collaboration of health care professionals aiming to improve neonatal care [18]. To contribute to the quality of neonatal care of very low birth weight infants, our NICU has been reporting data to the VON database since 2008. We performed a retrospective observational cohort study of mothers and infants admitted to Department of Perinatology at Maternity hospital Ljubljana, University Medical Centre Ljubljana, Slovenia. Our cohort consists of live born infants delivered or transferred to our center immediately after birth between 2013 and 2022 with GA from 22^{+0} to 24^{+6} weeks. Clinical data regarding prenatal care and neonatal outcomes of all live born infants were collected from our own submissions to the VON database. No individual patient data were analyzed. We investigated the following VON variables (definitions from the VON manual): magnesium sulfate (magnesium sulfate was administered intravenously to the mother during pregnancy at any time prior to delivery); antenatal corticosteroids (corticosteroids were administered IM or IV to the mother during pregnancy at any time prior to delivery. Corticosteroids include betamethasone, dexamethasone, and hydrocortisone); died in delivery room; died within 12 h of admission to your NICU; mortality excluding early deaths; survival; survival without specified morbidities defined as severe intraventricular hemorrhage (IVH) grade III – IV (periventricular-intraventricular hemorrhage (PIH), worst grade is III or IV), chronic lung disease (CLD; need for supplemental oxygen at 36 weeks Post Menstrual Age), necrotizing enterocolitis (NEC), pneumothorax, any late infection, or periventricular leukomalacia (PVL); initial resuscitation – surfactant; surfactant – at any time; NEC – surgery; severe intraventricular hemorrhage (IVH) grade III – IV; retinopathy of prematurity (ROP) – surgery; patent ductus arteriosus (PDA) – surgery; oxygen at 36 weeks postmenstrual age (PMA); oxygen at discharge home. Severe IVH is coded as "Yes" if PIH, worst grade is III or IV. Further detailed definitions of investigated variables are accessible in the VON Manual of operations [19].

Data are presented as numbers and percentage. Figures were created using GraphPad Prism 9.4.1 © GraphPad Software, LLC (Boston, MA, USA).

Results

Between 2013 and 2022, 185 live born infants with gestational age between 22^{+0} and 24^{+6} were born at or transferred within hours after birth to our level III NICU at Maternity hospital Ljubljana. Active management with any dose of antenatal corticosteroids was received by 16 % mothers of live born infants at completed 22 weeks, 59.3 % at 23 weeks and 87.7 % at 24 weeks completed gestation. Antenatal magnesium sulfate was administered intravenously to the infants' mothers during pregnancy at any time prior to delivery in 24 , 35.2 and 54.7 % at completed 22, 23 and 24 weeks' gestation (Table 1). Infant survival rate was 1/25 (4 %) at 22 weeks, 22/54 (40.7 %) at 23 weeks, and 69/107 (65.1 %) at 24 weeks of gestation (Figure 1). Rates of not actively treated live born infants that died in the delivery room were 23/25 (92 %) at 22 weeks, 13/54 (24.1 %) at 23 weeks and 7/106 (6.6 %) at 24 weeks gestation. Surfactant in the initial resuscitation or as part of the stabilization immediately after birth was given to none (0 %) of the infants born at 22 weeks, 3 (5.6 %) infants born at 23 weeks, and 7 (6.6 %) infants born at 24 weeks gestation. The main reason for "delayed" surfactant administration is the proximity of the NICU, which is located next to the delivery rooms; most periviable newborns with respiratory distress received this medication immediately upon admission to the NICU. Additional survival and mortality rates for all live born infants are listed in Figure 1.

For infants admitted to the NICU, early mortality rates (death within 12 h) were 1/2 (50 %) at 22 weeks, 3/41 (7.3 %) at 23 weeks and 3/99 (3 %) at 24 weeks. Rates of survival until

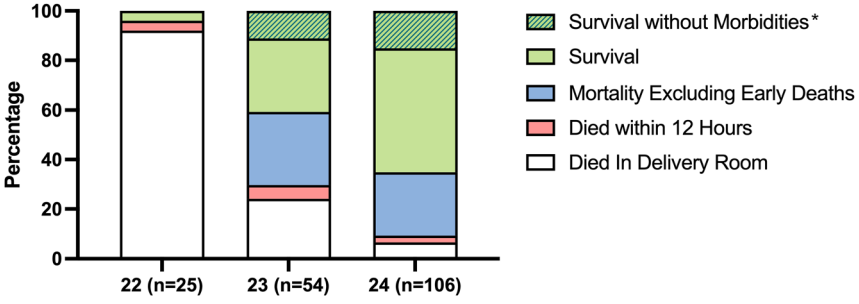

Figure 1: Survival, mortality and morbidity of liveborn infants between 2013 and 2022. Columns represent live born infants at completed 22, 23 and 24 weeks of gestation. Data are presented as percentage of all liveborn infants at each gestational week. *Morbidities in VON are defined as severe IVH (grade III and IV), periventricular leukomalacia, chronic lung disease, necrotizing enterocolitis, pneumothorax, or any late infection (after 72 h of age).

Table 1: Cohort characteristics among all infants by gestational age.

Gestational age, weeks	**22^{+0-6}**		**23^{+0-6}**		**24^{+0-6}**	
Liveborn infants, n	**25**		**54**		**106**	
Magnesium sulfate, n (%)	6	(24)	19	(35.2)	58	(54.7)
Antenatal corticosteroids, n (%)	4	(16)	32	(59.3)	93	(87.7)
Died in delivery room, n (%)	23	(92)	13	(24.1)	7	(6.6)
Died within 12 h of admission to NICU, n (%)	1	(4)	3	(5.6)	3	(2.8)
Mortality excluding early deaths, n (%)	0	(0)	16	(29.6)	27	(25.5)
Survival, n (%)	1	(4)	22	(40.7)	69	(65.1)
Survival without morbidities[a], n (%)	0	(0)	6	(11.1)	16	(15.1)
Initial resuscitation – surfactant, n (%)	0	(0)	3	(5.6)	7	(6.6)
Surfactant – at any time, n (%)	1	(4)	36	(66.7)	84	(79.2)
NEC – surgery, n (%)	0	(0)	4	(7.4)	15	(14.2)
IVH grade III – IV, n (%)	0	(0)	11	(29.4)	25	(23.6)
ROP – surgery, n (%)	1	(4)	8	(14.8)	16	(15.1)
PDA – surgery, n (%)	0	(0)	0	(0.0)	3	(2.8)
Oxygen at 36 weeks PMA, n (%)	0	(0)	15	(27.8)	43	(40.6)
Oxygen at discharge home, n (%)	0	(0)	10	(18.5)	32	(30.2)

Data from liveborn infants from 2013 to 2022 at level III NICU; results are reported on the infant level. [a]Morbidities in VON are defined as severe intraventricular hemorrhage (IVH; grade III, and IV), periventricular leukomalacia, chronic lung disease, necrotizing enterocolitis, pneumothorax, or any late infection (after 72 h of age). ROP, retinopathy of prematurity; PDA, patent ductus arteriosus; PMA, postmenstrual age.

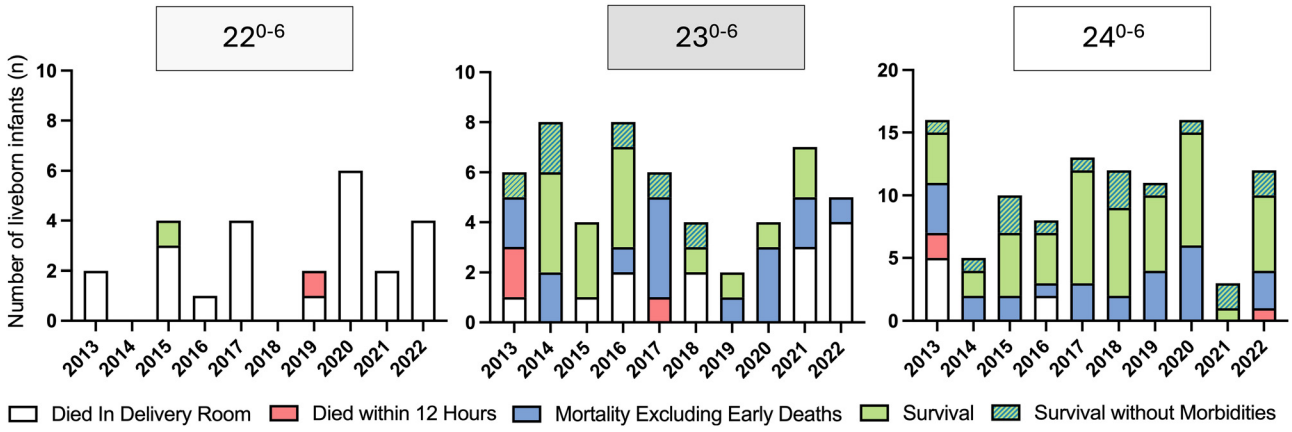

Figure 2: Temporal depiction of survival, mortality and morbidity of live born infants. Each histogram represents liveborn infants at completed 22, 23 and 24 weeks of gestation. Y axis represents the number of live born infants and X axis year of birth.

discharge for infants that survived 12 h were 1/1 (100 %) at 22 weeks, 22/38 (57.9 %) at 23 weeks, and 69/96 (71.9 %) at 24 weeks of gestation.

For all live born infants, survival rate without morbidities, defined as survival without any late infection (after 72 h of age), severe intraventricular hemorrhage (grade III and IV), periventricular leukomalacia, chronic lung disease, necrotizing enterocolitis or pneumothorax was 0 % at 22 weeks, 6/54 (11.1 %) at 23 weeks and 16/106 (15.1 %) at 24 weeks. Of the infants admitted to the NICU (n=142), 25.3 % had severe intraventricular hemorrhage (grade III or IV) or periventricular leukomalacia, 13.4 % underwent abdominal surgery (due to necrotizing enterocolitis), and 17.6 % required laser treatment for retinopathy of prematurity. Supplemental oxygen at 36 weeks PMA was required by 40.8 % infants. Further cohort characteristics by completed gestational age are listed in Table 1.

Temporal changes in number of live born infants, mortality and morbidity are illustrated in Figure 2. There were no changes in antenatal or neonatal management at our center during this 10-year period.

Discussion

We performed an observational retrospective cohort study to investigate rates of active antenatal care, mortality and morbidity for infants born between 22^{+0} and 24^{+6} weeks' gestation at Maternity hospital Ljubljana, Slovenia, between 2013 and 2022. We found very low rates of active prenatal care and actively treated infants born before 23 weeks, which reflect existing national guidelines. Survival rate of infants actively treated and alive at the age of 12 h was >50 % for all investigated gestational ages.

Periviable infants have better outcomes when mothers receive active prenatal care and give birth in tertiary centers with neonatal intensive care units [20–24]. However, vast ethical challenges regarding initiation of active maternal and infant care at periviable gestation remain an essential dimension of periviable birth management [7, 25]. Clinicians and families are often faced with difficult decisions while balancing survival with risk of disability and uncertain prognoses of periviable infants.

To facilitate best neonatal outcomes, actions such as maternal transfer "*in utero*", antenatal corticosteroids, tocolysis, antibiotic prophylaxis, and in some cases indication for caesarean section need to precede active neonatal approach at periviable gestation. During the study period, our national recommendations suggested active prenatal management from 24^{+0}, at earlier gestation only after individual consultation and agreement with the parents. Meta-analysis and retrospective observational studies have shown that exposure to prenatal corticosteroids significantly reduces mortality and morbidity rates for periviable infants [26–29]. Our results reflect our national guidelines as active care with any dose of antenatal corticosteroids was received by only 16 % mothers of live born infants at completed 22 weeks gestation. Compared with results from 636 US NICUs level III and IV, 56 % of women received at least one dose of corticosteroids at 22 weeks [16]. Our result for subsequent gestational weeks approach data from VON which report >85 % of women after 23 and 24 weeks gestation received at least one dose of antenatal corticosteroids [16]. In our center, it was 59.3 % at 23 and 87.7 % at 24 weeks completed gestation. There is limited evidence for recommendations of magnesium sulfate administration for neuroprotection in the periviable gestation [30]. Existing evidence suggests a reduction of the risk of cerebral palsy in

surviving infants [31]. Further, exposure to both antenatal corticosteroids and magnesium sulfate may reduce severe neurodevelopmental impairment or death [32]. The rates of antenatal magnesium sulfate administration in our center were lower compared to the recently published VON data, with 24 % (VON 44.3 %) at 22, 35.2 % (VON 74.9 %) at 23, and 54.7 % (VON 79.0 %) at 24 completed weeks of gestation. The differences at gestational weeks 22 and 23 reflect our national guidelines during the study period. At 24 weeks gestation, a closer look at maternal data would be needed to further explore if lower rates are the result of individual decisions to withhold active management, challenges in guideline implementation or unfeasibility to practice active management due to imminent birth.

As per our national guidelines, we did not actively approach liveborn infants at 22 weeks' gestation resulting in over 90 % of them dying in the delivery room. The remaining two infants, of which one survived until discharge, are not sufficient to present a reliable survival rate for our cohort. Across other level III and IV NICUs, rate of active approach has increased in the last years, reaching any support being given to 68.0 % at 22 weeks [16]. In Sweden, an uniformly active approach to infants born from 22^{+0} weeks gestational resulted in comparable survival rates across 22, 23, and 24 weeks of gestation [17]. Since 2016, their national guidelines on active management of infants including centralization, antenatal corticosteroids, mode of delivery and resuscitation of infants from 22^{+0} weeks of gestation resulted in reduced mortality and greater chances of survival without major neonatal morbidities [12]. Between 2004 and 2019, their one-year survival of live born infants increased from 4 to 25 % at 22 and 53–67 % at 23 weeks' gestation [12]. Reassuringly, their increase in survival was not accompanied by higher rates of major neonatal morbidities, which remained similar between infants born at 22 and 23 weeks [12]. However, the increase in survival at 22 weeks was evident until 2016 and not subsequently. Similarly, across other level III and IV NICUs, survival of infants born at 22 weeks remains between 25 and 50 % despite increased rates of active management without a convincible trend to further improvement [16, 33–36]. The biologically immaturity of infants as 22 weeks may often still be insurmountable with today's intensive care treatment options [37].

Rates of active treatment and survival at later gestational weeks align our center closer to those reported in the literature. After completed 23 weeks of gestation 75.9 % of live born infants were admitted to the NICU. Total survival rates for all live born infants at 23 weeks were 40.7 %, and 57.9 % for infants that survived>12 h. Compared to Sweden, their survival rates for infants admitted to the NICU increased from 65 to 70 % between 2004 and 2019 [12]. Lower survival rates may reflect our national guidelines that do not dictate a uniformly active antenatal and neonatal approach at 23 weeks. Reassuringly, rate of morbidities among survivors was similar, with 11.1 % at our center and between 11 and 17 % in Sweden [12]. Of note, our data from VON include late onset infection as a morbidity, which was not included in the Swedish major neonatal morbidity outcome [12]. At completed 24 weeks of gestation, our center achieved comparable survival rates as published in the literature. 70 % of infants admitted to the NICU survived until discharge. Comparable NICUs included reported roughly 70 % survival at 24 weeks of gestation and 26.5 % survival without comparable morbidities which is slightly higher than achieved in our center (15.1 % for all live born infants) [16, 17]. Higher rates of active management for earlier gestation have been shown to improve outcomes of other very preterm infants, which could possibly explain higher rates of morbidity free survival at 24 weeks in centers with a more active approach from 22^{+0} weeks compared to ours [13, 14, 16].

Imminent periviable preterm birth, particularly at 22 weeks, poses several ethical dilemmas including how to define viability, whether to initiate or withhold intensive care, and especially the uncertainty to predict long-term outcomes including quality of life and risk of severe neurological disability [5]. Studies have reported no neurological impairment in only 20 % of infants born between 22 and 24 weeks, while survival without moderate to severe neurological impairment ranged from 40 to 80 % [15, 38–41]. These considerations, along with resource allocation and societal impact, need to be carefully evaluated to ensure ethically sound, evidence-based decision making in the care of periviable infants. Further, there are still gaps in the knowledge of periviable infants' health and quality of life as older children and young adults. We plan to continue monitoring our study cohort and report their long-term outcomes in the future.

Limitations of our study include large variation in small number of patients born at investigated gestational ages. A larger cohort would enable further analyses. Further, our selective approach for infants born <24 weeks of gestation likely introduced selection bias, potentially inflating survival rates, as infants admitted to the NICU were those considered to have a better initial prognosis. Additionally, a time-series analysis investigating results of implemented changes in our approach towards periviable infants will represent a central focus of investigation in the future.

Periviable care remains challenging for obstetricians and neonatologists and will continue to change limits of

physiology and ethics. Rigorous research, collaborative databases, centers of excellence and specialized clinical approaches are needed to allow for informed dialog between families and clinicians [20]. Active antenatal practices at gestation from 22^{+0} weeks have been shown to increase survival without increase in major neonatal morbidities. However, as morbidity free survival rates remain low, the decision on active infant management should be individualized, family oriented, with antenatal parent counselling as a key component. In the future, we will carefully consider implementing active antenatal care for pregnant women and infants born after completed 22 weeks of gestation, and further monitoring of the long-term outcomes for all infants born at the border of viability. This will require clearly defined protocols, establishing criteria for initiating intensive care, multidisciplinary team collaboration with family's involvement leading to shared decision making, with common aim to ensure ethical and evidence-based periviable care. Importantly, our focus must extend beyond NICU discharge, to include later assessments of physical, and cognitive development throughout childhood. Emerging technologies, such as artificial womb systems, may further influence viability thresholds and should be considered in future planning and research.

Research ethics: Not applicable. Ethical Approval was not required as our study involved the analysis of aggregated, anonymized data from our own submission to an existing database. No identifiable individual patient information was analyzed.

Informed consent: Not applicable. Not required due to anonimous data entry.

Author contributions: Study design and conceptualization, statistical analysis, interpretation of data: all authors. Drafting of manuscript: PR. Critical revision of manuscript: all authors. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Data availability: All data relevant to the study are included in the article.

References

1. Pignotti M. The definition of human viability: a historical perspective. Acta Paediatr 2010;99:33–6.
2. Lagercrantz H. The emergence of the mind – a borderline of human viability? Acta Paediatr 2007;96:327–8.
3. Blackmon LR. Biologic limits of viability: implications for clinical decision-making. NeoReviews 2003;4:e140–6.
4. Skupski DW, Chervenak FA, McCullough LB, Bancalari E, Haumont D, Simeoni U, et al. Ethical dimensions of periviability. J Perinat Med 2010; 38:579–83.
5. Stanojevic M. Limits of viability: should we play god? Psychiatr Danub 2021;33:S280–91.
6. National Institute for Public Health. Perinatal informational system [Electronic]. https://www.nijz.si/sl/podatki/perinatalni-informacijski-sistem [Accessed on 20 Dec 2024].
7. Kornhauser Cerar L, Lucovnik M. Ethical dilemmas in neonatal care at the limit of viability. Children 2023;10:784.
8. Raju TNK, Mercer BM, Burchfield DJ, Joseph GF. Periviable birth: executive summary of a joint workshop by the Eunice kennedy shriver national institute of child health and human development, society for maternal-fetal medicine, American academy of pediatrics, and American college of obstetricians and gynecologists. J Perinatol 2014; 34:333–42.
9. Koc E, Unal S. Viability of extremely premature neonates: clinical approaches and outcomes. J Perinat Med 2025;53:706–15.
10. Gadsbøll C, Björklund LJ, Norman M, Abrahamsson T, Domellöf M, Elfvin A, et al. Centralisation of extremely preterm births and decreased early postnatal mortality in Sweden, 2004-2007 versus 2014-2016. Acta Paediatr 2025;114:319–31.
11. Litmanovitz I, Reichman B, Arnon S, Boyko V, Lerner-Geva L, Bauer-Rusak S, et al. Perinatal factors associated with active intensive treatment at the border of viability: a population-based study. J Perinatol 2015;35:705–11.
12. Farooqi A, Hakansson S, Serenius F, Kallen K, Björklund L, Normann E, et al. One-year survival and outcomes of infants born at 22 and 23 weeks of gestation in Sweden 2004-2007, 2014-2016 and 2017-2019. Arch Dis Child Fetal Neonatal Ed 2023;109:10–7.
13. Syltern J. Scandinavian perspectives on life support at the border of viability. Front Pediatr 2024;12:1394077.
14. Smith PB, Ambalavanan N, Li L, Cotten CM, Laughon M, Walsh MC, et al. Approach to infants born at 22 to 24 weeks' gestation: relationship to outcomes of more-mature infants. Pediatrics 2012; 129:e1508–16.
15. Rysavy MA, Mehler K, Oberthür A, Ågren J, Kusuda S, McNamara PJ, et al. An immature science: intensive care for infants born at ≤23 weeks of gestation. J Pediatr 2021;233:16–25.e1.
16. Edwards EM, Ehret DEY, Soll RF, Horbar JD. Survival of infants born at 22 to 25 weeks' gestation receiving care in the NICU: 2020-2022. Pediatrics 2024;154. https://doi.org/10.1542/peds.2024-065963.
17. Söderström F, Normann E, Jonsson M, Ågren J. Outcomes of a uniformly active approach to infants born at 22-24 weeks of gestation. Arch Dis Child Fetal Neonatal Ed 2021;106:413–7.
18. Vermont Oxford network database summary for infants 501 to 1500 grams. Burlington, VT: Vermont Oxford Network.
19. Vermont Oxford Network. Manual of operations: part 2. Data definitions and infant data booklets for infants born in 2022. 26.2. https://vtoxford.zendesk.com/hc/en-us/articles/4405064008467-

2022-Manual-of-Operations-Part-2-Release-26-2-PDF [Accessed 15 Jan 2024].
20. Bernardini LB, Healy H, Battarbee AN, Brennick E, Church P, Pavlek LR, et al. It's the little things. A framework and guidance for programs to care for infants 22–23 weeks' gestational age. J Perinatol 2025. https://doi.org/10.1038/s41372-025-02252-x.
21. Helenius K, Longford N, Lehtonen L, Modi N, Gale C. Association of early postnatal transfer and birth outside a tertiary hospital with mortality and severe brain injury in extremely preterm infants: observational cohort study with propensity score matching. BMJ 2019;367:l5678.
22. Shipley L, Hyliger G, Sharkey D. Temporal trends of in utero and early postnatal transfer of extremely preterm infants between 2011 and 2016: a UK population study. Arch Dis Child Fetal Neonatal Ed 2022;107:201–5.
23. Hohlagschwandtner M, Husslein P, Klebermass K, Weninger M, Nardi A, Langer M, et al. Perinatal mortality and morbidity. Comparison between maternal transport, neonatal transport and inpatient antenatal treatment. Arch Gynecol Obstet 2001;265:113–8.
24. Phibbs CS, Baker LC, Caughey AB, Danielsen B, Schmitt SK, Phibbs RH, et al. Level and volume of neonatal intensive care and mortality in very-low-birth-weight infants. N Engl J Med 2007;356:2165–75.
25. Arimitsu T, Hatayama K, Gaughwin K, Kusuda S. Ethical considerations regarding the treatment of extremely preterm infants at the limit of viability: a comprehensive review. Eur J Pediatr 2025;184:140.
26. Ehret DEY, Edwards EM, Greenberg LT, Bernstein IM, Buzas JS, Soll RF, et al. Association of antenatal steroid exposure with survival among infants receiving postnatal life support at 22 to 25 weeks' gestation. JAMA Netw Open 2018;1:e183235.
27. Park CK, Isayama T, McDonald SD. Antenatal corticosteroid therapy before 24 weeks of gestation: a systematic review and meta-analysis. Obstet Gynecol 2016;127:715–25.
28. Chawla S, Wyckoff MH, Rysavy MA, Patel RM, Chowdhury D, Natarajan G, et al. Association of antenatal steroid exposure at 21 to 22 weeks of gestation with neonatal survival and survival without morbidities. JAMA Netw Open 2022;5:e2233331.
29. McGoldrick E, Stewart F, Parker R, Dalziel SR. Antenatal corticosteroids for accelerating fetal lung maturation for women at risk of preterm birth. Cochrane Database Syst Rev 2020;12:CD004454.
30. Crowther CA, Middleton PF, Voysey M, Askie L, Duley L, Pryde PG, et al. Assessing the neuroprotective benefits for babies of antenatal magnesium sulphate: an individual participant data meta-analysis. PLoS Med 2017;14:e1002398.
31. Wolf HT, Huusom LD, Henriksen TB, Hegaard HK, Brok J, Pinborg A. Magnesium sulphate for fetal neuroprotection at imminent risk for preterm delivery: a systematic review with meta-analysis and trial sequential analysis. BJOG 2020;127:1180–8.
32. Gentle SJ, Carlo WA, Tan S, Gargano M, Ambalavanan N, Chawla S, et al. Association of antenatal corticosteroids and magnesium sulfate therapy with neurodevelopmental outcome in extremely preterm children. Obstet Gynecol 2020;135:1377–86.
33. Kono Y, Yonemoto N, Nakanishi H, Kusuda S, Fujimura M. Changes in survival and neurodevelopmental outcomes of infants born at <25 weeks' gestation: a retrospective observational study in tertiary centres in Japan. BMJ Paediatr Open 2018;2:e000211.
34. Watkins PL, Dagle JM, Bell EF, Colaizy TT. Outcomes at 18 to 22 months of corrected age for infants born at 22 to 25 weeks of gestation in a center practicing active management. J Pediatr 2020;217:52–8.e1.
35. Mehler K, Oberthuer A, Keller T, Becker I, Valter M, Roth B, et al. Survival among infants born at 22 or 23 weeks' gestation following active prenatal and postnatal care. JAMA Pediatr 2016;170:671–7.
36. Backes CH, Söderström F, Ågren J, Sindelar R, Bartlett CW, Rivera BK, et al. Outcomes following a comprehensive versus a selective approach for infants born at 22 weeks of gestation. J Perinatol 2019;39:39–47.
37. Kozlov M. Human trials of artificial wombs could start soon. Here's what you need to know. Nature 2023;621:458–60.
38. Younge N, Goldstein RF, Bann CM, Hintz SR, Patel RM, Smith PB, et al. Survival and neurodevelopmental outcomes among periviable infants. N Engl J Med 2017;376:617–28.
39. Moore T, Hennessy EM, Myles J, Johnson SJ, Draper ES, Costeloe KL, et al. Neurological and developmental outcome in extremely preterm children born in England in 1995 and 2006: the EPICure studies. BMJ 2012;345:e7961.
40. Pierrat V, Marchand-Martin L, Arnaud C, Kaminski M, Resche-Rigon M, Lebeaux C, et al. Neurodevelopmental outcome at 2 years for preterm children born at 22 to 34 weeks' gestation in France in 2011: EPIPAGE-2 cohort study. BMJ 2017;358:j3448.
41. Lorthe E, Torchin H, Delorme P, Ancel PY, Marchand-Martin L, Foix-L'Hélias L, et al. Preterm premature rupture of membranes at 22-25 weeks' gestation: perinatal and 2-year outcomes within a national population-based study (EPIPAGE-2). Am J Obstet Gynecol 2018;219:298.e1–14.