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ORIGINAL ARTICLE

Preterm birth in the Nordic countries—Capacity, management and outcome in neonatal care

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Abstract

Aim: Organisation of care, perinatal and neonatal management of very preterm infants in the Nordic regions were hypothesised to vary significantly. The aim of this observational study was to test this hypothesis.

Methods: Information on preterm infants in the 21 greater healthcare regions of Denmark, Finland, Iceland, Norway and Sweden was gathered from national registers in 2021. Preterm birth rates, case-mix, perinatal interventions, neonatal morbidity and survival to hospital discharge in very (<32 weeks) and extremely preterm infants (<28 weeks of gestational age) were compared.

Abbreviations: CI, confidence interval; EPT, extremely preterm; GA, gestational age; NICU, neonatal intensive care unit; SD, standard deviation; VPT, very preterm.

Results: Out of 287 642 infants born alive, 16 567 (5.8%) were preterm, 2389 (0.83%) very preterm and 800 (0.28%) were extremely preterm. In very preterm infants, exposure to antenatal corticosteroids varied from 85% to 98%, live births occurring at regional centres from 48% to 100%, surfactant treatment from 28% to 69% and use of mechanical ventilation varied from 13% to 77% ($p < 0.05$ for all comparisons). Significant regional variations within and between countries were also seen in capacity in neonatal care, case-mix and number of admissions, whereas there were no statistically significant differences in survival or major neonatal morbidities.

Conclusion: Management of very preterm infants exhibited significant regional variations in the Nordic countries.

KEYWORDS

gestational age, mortality, neonatal care, Nordic country, premature

1 | INTRODUCTION

The overall health of the 28 million people living in the Nordic countries Denmark, Finland, Iceland, Norway and Sweden has been good for decades. This includes reproductive health for pregnant women. The Nordic perinatal healthcare services have, with few exceptions, been public and free of charge. The access and adherence to antenatal healthcare programmes have been almost universal. These factors and low poverty rates have contributed to low and decreasing rates of stillbirths and infant mortality, as well as to overall low preterm birth rates in all five countries.[1–3]

While these developments have been gratifying, there are still unresolved issues around preterm birth. Preterm birth rates have been reported to decrease in all Nordic countries except in Iceland,[3] but the within country variation in preterm birth rates has been reported to be significant, even after adjusting for known risk factors.[4] Large and unexplained regional variation has also been reported for very preterm infant mortality in Europe.[5] These findings may suggest inequity in the quality of perinatal and neonatal care, or differential exposure to risk factors, or both.

Identifying strengths and challenges in comparable settings could help to improve quality of care and aid research. It could also empower families, and inform healthcare providers on management and consequences of preterm birth.[6,7] The main aim of this population-based cohort study was to compare preterm birth rates, capacity in neonatal care, as well as selected management and outcomes for very preterm (VPT) infants in 21 Nordic healthcare regions.

Key Notes

- Organisation of neonatal care and perinatal management of very preterm infants have not been benchmarked in the Nordic countries.
- In this study of 2389 very preterm infants born in 2021, birth rates, capacity in neonatal care and perinatal management exhibited significant regional variations across the 21 Nordic regions.
- Identifying strengths and challenges in comparable settings could help to improve quality of care, guide further research and empower families.

2 | METHODS

2.1 | Study population

The study included all preterm births in 2021 resulting in a live born infant as defined by WHO.[8] Stillbirths were not included because of lack of information in the neonatal registers. The organisation of neonatal care in four countries comprised of four to six geographical healthcare regions (Figure 1 and Table S1). Each region was typically served by a regional, university hospital with one or two level III–IV neonatal intensive care units (NICU) and several surrounding level I–II hospitals. Iceland, with a population of 376 000 people, was in this study considered as both a region and a country. Each infant's regional assignment was based on the family's region of residency (Iceland and Sweden) or region of birth (Denmark, Finland and Norway).

2.2 | Data sources

Data from Denmark were aggregated by the Danish Newborn Quality Database[9] and the Danish National Quality Database for Births.[10] The two databases were established in 2016 and 2010, respectively, and included all infants born alive in Denmark. Both databases were based on the Danish National Patient Registry, containing mandatory registrations by all 21 maternity units, four level

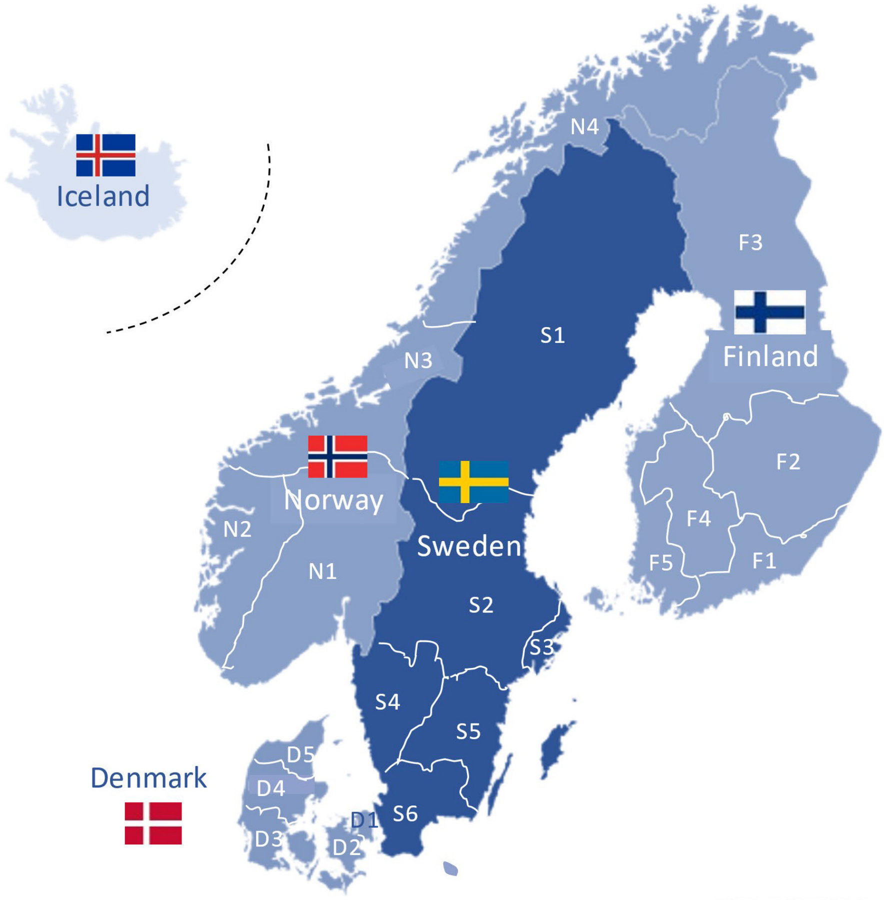

FIGURE 1 Map of the Nordic countries with greater regions of neonatal care, each typically served by one-two regional centres with a co-localised risk appropriate delivery unit and level III-IV neonatal intensive care unit. For further information on each region, please see Table S1.

III–IV NICUs and 14 level II NICUs. Civil registration numbers given to all mothers and liveborn infants made it possible to link the data to other databases.

Finnish data were extracted from the Medical Birth Register, which has incorporated a data file on preterm infants since 1 November 2004. Besides common information for all newborn infants, additional data were collected in a separate form on all live births in Finland with a birthweight≤1500 g or with a gestational age (GA) of less than 32 weeks. The data were collected until the infant reached 42 weeks of corrected GA.[11]

Data from Iceland were aggregated from the Birth Register of Iceland and the Children's Hospital NICU patient data registry.[12]

The Norwegian Neonatal Network had a population-based national quality registry which included all infants admitted for neonatal care. Detailed clinical data on treatment modalities and invasive procedures, diagnoses and clinical outcomes were registered daily in an electronic database.[13] All 21 Norwegian neonatal units have reported to the Neonatal Network since 2012, with a 100% coverage on VPT live born infants.

Swedish data originated from the Swedish Neonatal Quality Register. All 37 neonatal units have been reported to the Swedish Neonatal Quality Register since 2011, including eight centres with level III–IV NICUs, 28 level-II units of which 22 provided partial intensive care and one unit with neonatal care for near-term or term deliveries only with no intensive care. Data collection was performed daily in 34/37 units, and the completeness has been found to be excellent for VPT infants.[14]

2.3 | Variables

The total numbers of liveborn infants in each country and region were captured from open access vital statistics including delivery room deaths. The proportions of infants admitted for neonatal care were calculated from neonatal register data.

Gestational age (GA) was defined by ultrasound in >95% of the pregnancies. Preterm birth was categorised as GA <37 weeks (preterm), <32 weeks (VPT) or <28 weeks (extremely preterm, EPT). Comparisons of case-mix, management and outcomes were restricted to VPT and EPT infants.

The capacity for neonatal care in each region was estimated by self-reported numbers of staffed and open neonatal beds in 2021 per 1000 live births. Neonatal intensive care beds were defined as beds staffed and equipped for mechanical ventilation, hypothermia treatment or dialysis, excluding beds in the delivery or neonatal units used for resuscitation and stabilisation. Staff density or competences were not compared because of no data.

The regional distributions of infant sex, birthweight classes with 500 g increments, proportions of twins and triplets and of infants with Apgar scores 0–3 at 5 min of age were used to describe and compare case-mix. Categorisation of annual volumes of infants by birthweight and region was done according to Phibbs et al.[15]

Perinatal management among VPT and EPT infants included three interventions. Two of them, use of any antenatal corticosteroids and centralisation of care,[16] had more solid evidence-base than the third, C-section.[17] Two of the most important neonatal interventions in VPT infants were also included: any treatment with surfactant including less or minimally invasive ways of administration, and mechanical ventilation[18] defined as any use of mechanical ventilatory support administered via an endotracheal tube.

Outcomes among EPT survivors selected for regional comparisons included three morbidities. The first was intraventricular haemorrhage (IVH) grade III–IV[19] or cystic periventricular leukomalacia (cPVL). The second was treated retinopathy of prematurity (ROP). The third was bronchopulmonary dysplasia (BPD), defined as use of supplemental oxygen or any mechanical respiratory pressure support at postmenstrual age of 36 weeks and 0 days. Survival to hospital discharge among liveborn VPT and EPT infants and in those admitted for neonatal care were also determined.

All data presented were aggregated from national, population-based registers or databases and no personal data were handled. Therefore, the project did not involve research according to the ethical review acts of the participating countries and the study protocol was not submitted for institutional ethical review.

2.4 | Statistical analyses

Data are described as mean and standard deviation, as well as numbers and proportions, with 95% confidence intervals (CI). Imputation of missing data was not performed because the study was exploratory and descriptive by design. For the same reason, no sample size or power calculations were performed. CIs without any overlap were considered as indicators of a statistically significant difference.

Calculations and graphics were performed using Excel 365 (Microsoft Corporation) and JavaStat 2022 (Interactive Statistical Pages project, https://statpages.info/ctab2x2).

3 | RESULTS

3.1 | Preterm birth rates

In 2021, there were 287 642 infants born alive in the Nordic countries out of which 16 567 (5.8%) were born preterm. The proportions of preterm infants varied between countries from 5.5% (95% CI 5.4–5.6) in Sweden to 6.2% (95% CI 6.0–6.4) in Denmark. The preterm birth rate in the 21 regions varied from 5.2% (95% CI 4.9–5.4) in eastern Sweden and 5.2% in mid-Norway, to 7.3% (95% CI 6.6–8.0) in northern Denmark. The proportions of VPT infants varied two-fold from 0.63% (95% CI 0.45–0.87) in eastern Finland to 1.2% (95% CI 0.90–1.5) in northern Denmark. The proportions of EPT infants varied three-fold from 0.13% (95% CI 0.06–0.26) in eastern Finland to 0.39% (95% CI 0.25–0.59) in northern Denmark, Table S2.

3.2 | Capacity in neonatal care

The mean (SD) Nordic bed capacity in neonatal care amounted to 4.7 (1.1) beds per 1000 live births, and the mean number of NICU beds was 1.3 (0.71) per 1000 live births. The lowest number of neonatal beds was reported from eastern Sweden (2.6/1000 live births) and the highest from eastern Finland (7.3/1000 live births). The lowest number of NICU beds was reported from southern Denmark (0.2/1000 live births) and the highest in eastern Finland (3.0/1000 live births), Figure 2. The mean neonatal admission rate for all GAs was 11% and varied from 7.0% to 15% in the 21 Nordic regions, Table S3.

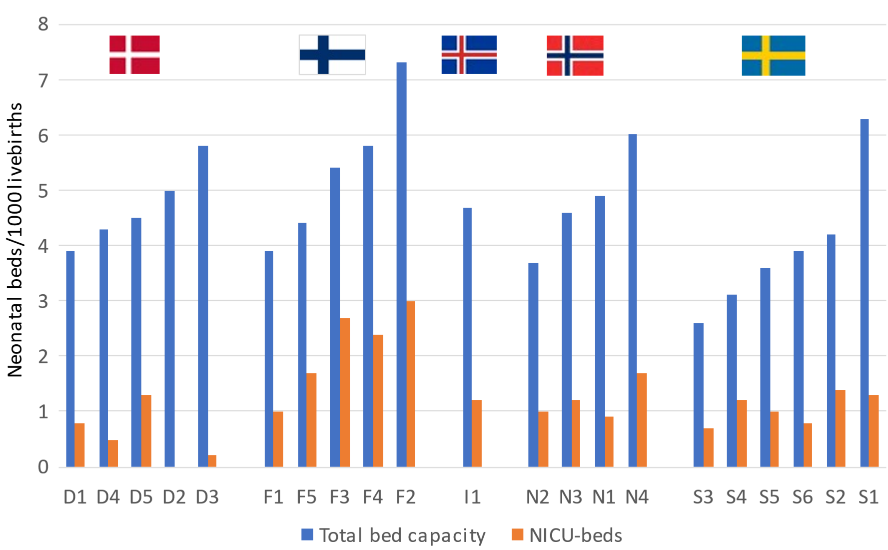

FIGURE 2 Capacity (neonatal beds/1000 liveborn infants in 2021) in Nordic neonatal care by the 21 greater healthcare regions. Total bed capacity: total number of beds per neonatal unit that were equipped and staffed in 2021. NICU bed: bed for neonatal intensive care (mechanical ventilation, dialysis, cooling therapy), excluding emergency room bed used for stabilisation (in delivery or neonatal unit).

3.3 | Case-mix and annual volumes of VPT

The case-mix of VPT infants in the 21 regions is presented in Table 1. A male preponderance was seen in most regions, with a variation from 38% on Iceland and in mid-northern Norway, to 62% in mid-Denmark. The proportion of twins and triplets varied from 13% (95% CI 7.3–20) in mid-Denmark to 36% (95% CI 24–49) in western Finland. The proportion of VPT infants with Apgar scores 0–3 at 5 min of postnatal age varied from 0% (95% CI 0–9.2) in eastern Finland, 2.0% (95% CI 0.2–7.1) in western Norway and 2.4% (95% CI 0.8–5.6) in the Capital region of Denmark, to 12% (95% CI 6.8–20) in southeast of Sweden and 12% (95% CI 6.8–18) in southern Finland.

Seven of 21 (33%) regions reported an annual admission number of more than 100 liveborn very low birthweight (<1500 g) infants. Five regions (24%) reported 50–100, and nine regions (43%) reported less than 50 very low birthweight admissions. The annual number of admissions of infants with a birthweight <500 g was equal to or less than 10 in all regions and 15/21 (71%) regions had less than 50 admissions of infants with a birthweight <1000 g.

3.4 | Perinatal interventions

The use of perinatal interventions for VPT birth in the Nordic regions is shown in Table 2. Use of antenatal corticosteroids in EPT infants born alive varied from 81% (95% CI 67–91) in mid-Sweden to 100% in mid-Norway, eastern and western Finland. In infants of 28–31 weeks GA, use of antenatal corticosteroids varied from 81% (95% CI 65–92) in northern Sweden to 98% (95% CI 88–100) in western Finland and 100% in Iceland. There were no available data on use of antenatal corticosteroids from Denmark.

The mean C-section rate at less than 28 weeks of GA in the Nordic countries was 54% and there were no statistically significant regional differences. At 28–31 weeks of GA, the mean C-section rate was 67% with a variation from 41% (95% CI 29–53) in mid-Norway to 79% (95% CI 66–88) in southern Denmark.

In southern Denmark, 62% (95% CI 44–78) of EPT live births occurred in a hospital with a level III–IV NICU, whereas all (100%) EPT live births in eight regions (one in Denmark, four in Finland, one in Iceland and two in Norway) took place at a level III–IV NICU centre. The proportion of live births at 28–31 weeks of GA occurring at a level III–IV centre varied from 29% (95% CI 21–38) in southern Sweden to 100% in northern Norway and Iceland, Figure 3 and Table S4.

3.5 | Neonatal interventions

Surfactant treatment of EPT infants ranged from 50% (95% CI 32–68) in southern Denmark to 93% (95% CI 78–99) in western Norway and 100% (8/8) in northern Norway. At 28–31 weeks GA, the proportions of infants treated with surfactant varied from 10% (95% CI 2.0–26) in Iceland to 65% (95% CI 46–80) in northern Finland, Figure 4 and Table S5.

Any mechanical ventilation of EPT infants varied from 38% (3/8) in northern Norway and 45% (95% CI 24–68) in northern Denmark, to 100% (95% CI 80–100) in western Finland. At 28–31 weeks of GA, use of mechanical ventilation varied from 6.5% (95% CI 0.8–21) in northern Norway to 74% (95% CI 56–87) in northern Finland, Figure 4 and Table S5.

3.6 | Survival and neonatal morbidities among survivors

In infants born alive at 22–24 weeks of GA, rates of NICU admissions were 73% (95% CI 59–84) in Denmark; 80% (95% CI 65–90) in Finland; 67% (95% CI 30–93) in Iceland; 92% (95% CI 83–97) in Norway and 98% (95% CI 94–100) in Sweden. Liveborn infants at 25–27 and at 28–31 weeks' GA were almost universally admitted for neonatal care, irrespective of region or country.

Among VPT-liveborn infants and in those admitted for care, there were no statistically significant differences in survival between regions or countries, Table S6 and Table 3 respectively. The overall Nordic survival among liveborn infants was 58% (95% CI 52–64) at 22–24 weeks, 91% (95% CI 88–93) at 25–27 and 98% (95% CI 97–98) at 28–31 weeks of GA. Among admitted infants, survival was 66% (95% CI 59–71) at 22–24 weeks, 92% (95% CI 89–94) at 25–27 and 98% (95% CI 97–99) at 28–31 weeks of GA.

Neonatal morbidities in EXT survivors are presented in Table 4. There were no statistically significant differences in IVH3-4/cPVL, treated ROP or BPD between regions or countries. The mean rate of IVH3-4/cPVL (Denmark excluded because of incomplete data) at 22–24 weeks of GA was 12% (95% CI 7.1–18) and at 25–27 weeks GA it was 7.9% (95% CI 5.3–11). The corresponding rates for treated ROP were 27% (95% CI 20–34) and 5.3% (95% CI 3.4–7.7), and for BPD (Denmark excluded because of incomplete data) the corresponding rates were 70% (95% CI 62–77) and 41% (95% CI 36–46).

4 | DISCUSSION

This study benchmarked contemporary management of very preterm births and infants in 21 Nordic regions. In this setting, pronounced regional variations were found in terms of organisation of care and in use of perinatal and neonatal interventions thought to be essential for optimal outcome. Significant regional variations in preterm birth rates, capacity in neonatal care and case-mix were also demonstrated. Despite these differences, survival and rates of selected neonatal morbidities among EXP infants did not differ between the Nordic healthcare regions. However, we cannot exclude that in some of the groups, the numbers may have been too low to detect statistically significant differences in neonatal morbidity and mortality even if present.

TABLE 1 Very preterm infants (live births, GA <32 weeks) by sex, multiplicity (twins/triplets), Apgar score 0–3 at 5 min and birthweight classes. Nordic countries and healthcare regions 2021.

	Boys *n* (%)	Twins/triplets *n* (%)[a]	Apgar score 0–3 at 5 min *n* (%)[a]	Birthweight <1000 g *n* (%)[a]	Birthweight 1000- < 1499 g *n* (%)[a]	Birthweight ≥1500 g *n* (%)[a]
Denmark	307 (57% [53–61])	127 (24% [20–27])	26 (4.8% [3.2–7.0])	168 (32% [28–37])	207 (40% [36–44])	143 (28% [24–32])
D1-Capital Region	115 (56)	55 (27)	5 (2.4)	66 (34)	79 (41)	49 (25)
D2-East Region	24 (52)	13 (28)	3 (6.5)	4 (8.9)	25 (56)	16 (36)
D3-South Region	60 (58)	24 (23)	8 (7.7)	34 (34)	41 (41)	26 (26)
D4-Mid Region	73 (62)	15 (13)	6 (5.1)	45 (39)	37 (32)	34 (29)
D5-North Region	35 (54)	20 (31)	4 (6.5)	19 (31)	25 (40)	18 (29)
Finland[b]	162 (49% [43–54])	86 (26% [21–31])	27 (8.2% [5.4–12])	103 (31% [26–31])	123 (38% [33–44])	99 (31% [26–36])
F1-South Region	59 (43)	33 (24)	16 (12)	45 (33)	60 (43)	33 (24)
F2-East Region	20 (53)	10 (26)	0 (0)	9 (24)	14 (37)	15 (39)
F3-North Region	25 (53)	10 (21)	4 (8.5)	20 (43)	11 (23)	16 (34)
F4-Central Region	29 (59)	12 (24)	4 (8.2)	13 (27)	17 (35)	19 (39)
F5-West Region	29 (49)	21 (36)	3 (5.1)	16 (27)	27 (46)	16 (27)
Iceland	18 (38% [24–53])	16 (33% [20–48])	5 (10% [3.6–23])	13 (27% [15–42])	23 (48% [33–63])	12 (25% [14–40])
I1-Iceland	18 (38)	16 (33)	5 (10)	13 (27)	23 (48)	12 (25)
Norway	262 (53% [49–58])	139 (28% [24–32])	24 (4.9% [3.1–7.1])	184 (37% [32–41])	155 (31% [27–36])	155 (31% [27–36])
N1-Southeast	167 (57)	82 (28)	18 (6.2)	115 (40)	92 (32)	84 (29)
N2-West Region	55 (56)	32 (32)	2 (2.0)	36 (36)	24 (24)	39 (39)
N3-Mid Region	25 (38)	15 (23)	3 (4.6)	21 (32)	21 (32)	23 (35)
N4-North Region	15 (38)	10 (26)	1 (2.6)	12 (31)	18 (46)	9 (23)
Sweden	533 (54% [50–57])	227 (23% [21–26])	58 (5.9% [4.5–7.6])	308 (32% [29–35])	382 (39% [36–42])	285 (29% [26–32])
S1-North Region	36 (52)	12 (17)	6 (8.7)	23 (33)	30 (43)	16 (23)
S2-Mid Region	120 (60)	43 (22)	14 (7.0)	57 (28)	81 (41)	61 (31)
S3-East Region	131 (54)	56 (23)	9 (3.7)	86 (36)	93 (38)	63 (26)
S4-West Region	91 (51)	32 (18)	7 (4.0)	60 (34)	64 (36)	52 (29)
S5-Southeast	53 (50)	23 (22)	13 (12)	30 (29)	35 (33)	40 (38)
S6-South Region	102 (55)	61 (33)	9 (4.9)	52 (28)	79 (43)	53 (29)
Nordic countries, total	1282 (54% [52–56])	595 (25% [23–27])	140 (5.9% [5.0–6.9])	776 (33% [31–35])	890 (38% [36–40])	694 (29% [28–31])

[a]95% confidence intervals for proportions are presented for countries.

[b]Data from 2020 and information for 2021 are not yet available.

TABLE 2 Perinatal interventions in very preterm live births (GA <32 weeks; survivors and in-hospital deaths).

	Any antenatal steroids <28 weeks GA *n* (%)[a]	Any antenatal steroids 28–31 weeks GA *n* (%)[a]	C-section, <28 wks GA *n* (%)[a]	C-section, 28–31 weeks GA *n* (%)[a]
Denmark	No data	No data	90 (51% [43–58])	233 (70% [64–74])
D1-Capital Region	No data	No data	48/82 (59)	93/125 (74)
D2-East Region				28/39 (72)
D3-South Region			15/30 (50)	44/56 (79)
D4-Mid Region			19/43 (44)	42/73 (58)
D5-North Region			8/22 (36)	26/42 (62)
Finland	107 (95% [89–98])[b]	205 (95% [92–98])[b]	56 (58% [47–68])	159 (68% [62–74])
F1-South Region (Helsinki)	45 (94)	78 (95)	20 (50)	70 (72)
F2-East Region (Kuopio)	12 (100)	22 (92)	2 (25)	23 (77)
F3-North Region (Oulu)	16 (89)	32 (94)	14 (70)	16 (59)
F4-Central Region (Tampere)	17 (94)	27 (96)	9 (82)	22 (62)
F5-West Region (Turku)	17 (100)	46 (98)	11 (61)	28 (64)
Iceland	12 (86% [57–98])	31 (100% [89–100])	4 (29% [8.4–58])	15 (48% [30–67])
I1-Iceland	12 (86)	31 (100)	4 (29)	15 (48)
Norway	163 (96% [92–99])	288 (91% [87–94])	92 (53% [45–60])	192 (60% [54–65])
N1-Southeast Region	110 (95)	165 (95)	65 (57)	114 (65)
N2-West Region	26 (87)	58 (84)	13 (43)	28 (41)
N3-Mid Region	20 (100)	39 (89)	11 (52)	27 (61)
N4-North Region	7 (88)	26 (84)	3 (38)	23 (74)
Sweden	286 (93% [90–96])	530 (91% [88–93])	186 (57% [52–63])	452 (70% [66–73])
S1-North Region	27 (97)	30 (81)	17 (61)	28 (68)
S2-Mid Region	38 (81)[c]	109 (87)	28 (49)	105 (76)
S3-East Region	83 (97)	138 (96)	54 (62)	104 (68)
S4-West Region	48 (96)	112 (94)	35 (67)	89 (71)
S5-Southeast Region	30 (97)	49 (89)	19 (53)	45 (65)
S6-South Region	60 (92)	92 (88)	33 (51)	81 (68)
Nordic countries, total	568 (94% [92–96])	1054 (92% [90–93])	428 (54% [51–58])	1051 (67% [65–69])

[a]95% confidence intervals for proportions are presented for countries.
[b]Data from 2020.
[c]>20% missing data.

Proportions of preterm infants were found to differ more between regions than between countries. The regional differences were largest at the lowest gestational ages. Interestingly, even larger geographical differences in preterm birth rates than those described herein have been reported between municipalities, also after taking several known risk factors such as socio-economical differences into account.[4]

Capacity in neonatal care has not previously been described as a limiting factor in the Nordic countries. According to a study of bed supply in the USA, the number of neonatal and NICU beds reported from eastern Sweden (Capital region) could be categorised as very low capacity.[20] This bed shortage could exclusively be explained by a severe shortage of nurses (personal communication). Besides limited capacity for centralisation, the bed shortage in eastern Sweden has been associated with decreasing admission rates of term infants, and an increasing number of postnatal transports of preterm infants without a medical indication.[21] In contrast, Finland reported a very high NICU capacity in four out of five regions. The higher density of neonatal and NICU beds in Finland may reflect the 15% decrease in Finnish birth rates that have occurred between 2010 and 2021. Our findings and those of others[20] suggest that the variations in neonatal bed supply from very low to very high, may be related to factors other than patient needs. How this variation relates to the quality of care and other outcomes remains to be studied.

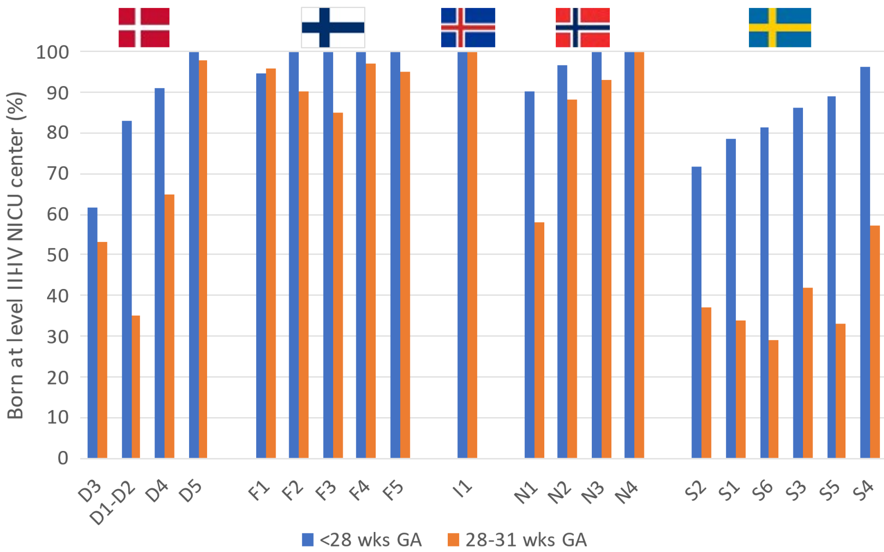

FIGURE 3 Proportions (%) of very preterm live births (GA <32 weeks; survivors and in-hospital deaths) born at centre with a level III–IV neonatal intensive care unit by Nordic healthcare region ($n = 21$, year 2021) and gestational age strata.

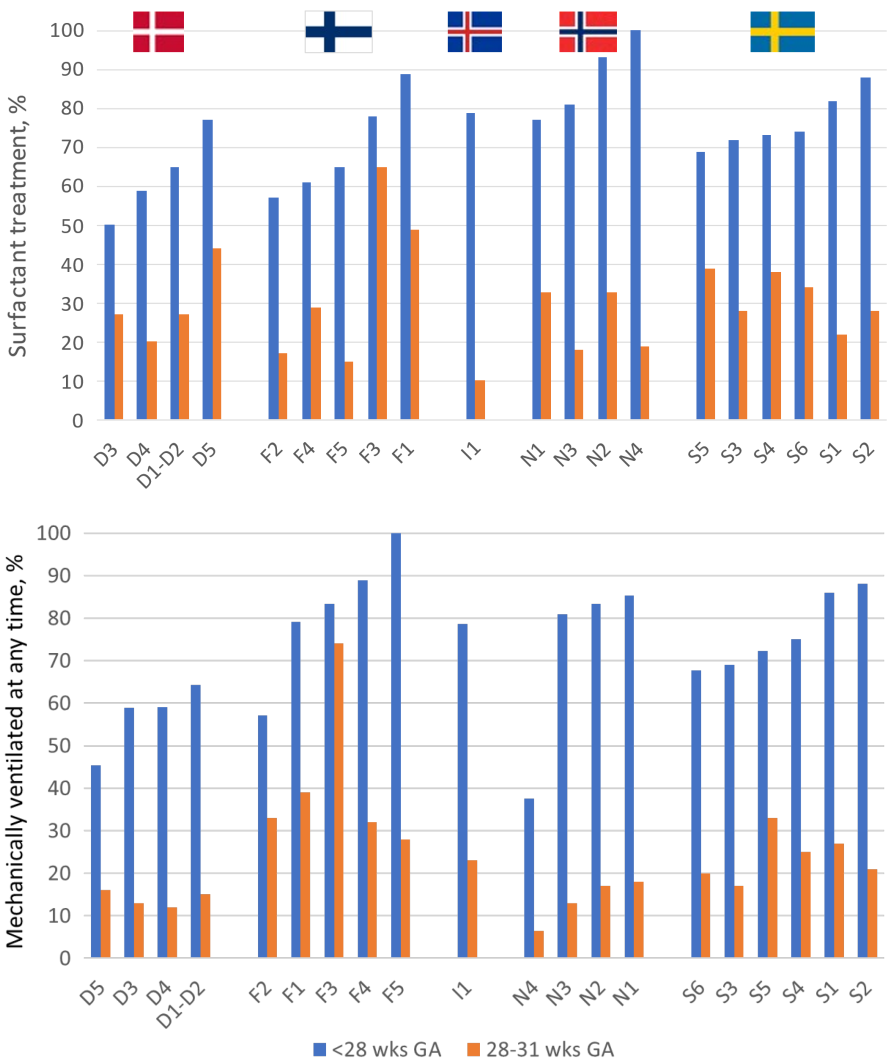

FIGURE 4 Proportion (%) of liveborn very preterm infants treated with surfactant (upper graph) and mechanically ventilated (lower graph) by Nordic region ($n = 21$, year 2021) and gestational age strata.

The regional variations in proportions of VPT twins and of VPT infants with Apgar scores 0–3 at 5 min exceeded the between-country variations. Random variation due to small sample sizes and different traditions for assignment of Apgar scores in VPT infants may have contributed to these observations. However, it cannot be excluded that there are underlying differences in regional obstetric and neonatal practices.

Antenatal corticosteroids were used in a high proportion of VPT infants in all regions, and C-section rates were with few exceptions not significantly different among regions. The lower proportion of

TABLE 3 Survival to hospital discharge in very preterm live births and among NICU admissions, including infants with malformations.

	Survival <25 weeks GA live births *n* (%)[a]	Survival <25 weeks GA admissions *n* (%)[a]	Survival 25–27 weeks GA live births *n* (%)[a]	Survival 25–27 weeks GA admissions *n* (%)[a]	Survival 28–31 weeks GA live births *n* (%)[a]	Survival 28–31 weeks GA admissions *n* (%)[a]
Denmark	25 (48% [34–62])	25 (66% [49–80])	116 (89% [82–93])	116 (90% [83–95])	347 (98% [96–99])	340 (98% [96–99])
Finland	27 (61% [46–76])	27 (77% [60–90])	59 (91% [81–97])	59 (92% [83–97])	198 (97% [94–99])	198 (98% [95–99])
Iceland	5 (56% [21–86])	5 (83% [36–100])	8 (100% [63–100])	8 (100% [63–200])	31 (100% [89–100])	31 (100% [89–100])
Norway	38 (59% [46–71])	38 (63% [50–75])	99 (91% [84–96])	99 (92% [84–96])	314 (98% [96–99])	314 (98% [96–99])
Sweden	71 (61% [52–70])	71 (62% [53–71])	195 (92% [87–95])	195 (92% [87–95])	634 (98% [96–99])	634 (98% [96–99])
Nordic countries, total	166 (58% [52–64])	166 (66% [59–71])	477 (91% [88–93])	477 (92% [89–94])	1524 (98%[97–98])	1517 (98%[97–99])

Note: Regional survival data are presented in Table S6.

[a]Proportions with 95% confidence intervals.

C-sections performed before 28 weeks of GA than at 28–31 weeks of GA is likely reflecting that foetal or maternal indications for operative delivery changes during pregnancy. The uncertain benefits of performing operative delivery for EPT births may also have played a role.[17] The C-section rates in EPT infants born in the Nordic countries were found to be lower than those reported from the United States and Germany.[22,23]

Centralisation of VPT and EPT births to regional centres with co-located level III-IV NICUs varied markedly between and within countries. While observational evidence from the Nordic countries[16,24] and the low volumes in each region[15] speak in favour of centralisation, centralised perinatal care of VPT births was practiced more strictly in Finland and Norway than in Denmark and Sweden. These findings may reflect differences in governance of the healthcare system and in capacity for partial intensive care at level-II neonatal units.[25] Previous difficulties in presenting a convincing survival advantage of centralising births at 28–31 weeks of GA may also have played a role.[26]

There were marked regional variations in respiratory management with a pattern of Danish units being less invasive than other Nordic regions. This may reflect the long-standing Danish tradition of using nasal continuous positive airway pressure as first choice respiratory support. However, this study did not take timing of the interventions into account, and therefore do not describe practices at birth. Less than 50% of infants born at 25–26 weeks of GA were intubated in the delivery room in Sweden.[18]

Rates of admission for neonatal intensive care among live births at 22–24 weeks of GA were lower in Denmark and Finland than in Norway and Sweden. This most likely reflects variations in attitudes and different guidelines on perinatal management at the border of viability. Interestingly, there were no significant differences between the Nordic countries in EPT survival among infants treated actively at birth. The same was found for the three neonatal morbidities selected. The present findings are in line with a comparison of outcomes for VPT infants born 10 years ago in two regions of Denmark and Sweden.[27] To provide reliable prognostic information and to assess regional variations in survival and outcome among infants with the highest risks born at 22 weeks of gestation, data need to be aggregated over longer periods of time. Follow-up after the neonatal period is also warranted. This could be a topic for future Nordic collaboration.

The limitations included the cross-sectional design without longitudinal data, small size of regions and subgroups which contributed to increased possibility of random variations and poor power. The number of staffed beds did not include any information on staff density or competence. The data were collected during the third and fourth waves of the COVID-19 pandemic which may have added to between country variations. However, even if exposure to SARS-CoV-2 and mitigation strategies varied in the Nordic countries, it is unlikely that these differences would have had a major influence on preterm birth rates[28] or outcomes for preterm infants,[29] especially as regional variations were found to be larger than national variations. Stillbirths were not controlled for which may have contributed

TABLE 4 Severe neonatal morbidity in extremely preterm survivors <28 weeks GA.

	IVH3-4/cPVL <25 weeks GA *n* (%)[a]	IVH3-4/cPVL 25–27 weeks GA *n* (%)[a]	Treated ROP <25 weeks GA *n* (%)[a]	Treated ROP 25–27 weeks GA *n* (%)[a]	BPD@36wPMA <25 weeks GA *n* (%)[a]	BPD@36wPMA 25–27 weeks GA *n* (%)[a]
Denmark	1 (4.0% [0.1–20])[b]	9 (7.8% [3.6–14])[b]	8 (32% [15–54])	10 (8.6% [4.2–15])	7 (28% [12–49])[b]	19 (16% [10–24])[b]
D1-Capital	1 (7.1)	5 (9.1)	5 (36)	4 (7.3)	3 (21)	3 (5.5)
D2-East						
D3-South	0 (0)	1 (4.5)	1 (33)	3 (14)	2 (67)	7 (32)
D4-Mid	0 (0)	2 (7.4)	2 (29)	2 (7.4)	2 (29)	5 (19)
D5-North	0 (0)	1 (8.3)	0 (0)	1 (8.3)	0 (0)	4 (33)
Finland	4 (14% [4.0–33])	4 (6.8% [1.9–16])	8 (29% [13–49])	6 (10% [3.8–21])	21 (70% [51–85])	24 (41% [28–54])
F1-South	3 (25)	4 (18)	5 (42)	3 (14)	12 (92)	11 (50)
F2-East	0 (0)	0 (0)	0 (0)	1 (11)	1 (33)	4 (44)
F3-North	1 (25)	0 (0)	2 (50)	0 (0)	1 (20)	2 (25)
F4-Central	0 (0)	0 (0)	0 (0)	2 (18)	3 (75)	3 (30)
F5-West	0 (0)	0 (0)	1 (20)	0 (0)	4 (80)	4 (40)
Iceland	2 (40% [5.3–85])	0 (0% [0–52])	3 (60% [15–95])	0 (0% [0–52])	3 (60% [15–95])	2 (25% [3.2–65])
I1-Iceland	2 (40)	0 (0)	3 (60)	0 (0)	3 (60)	2 (25)
Norway	3 (7.9% [1.7–21])	8 (8.1% [3.6–15])	6 (16% [6.0–31])	4 (4.0% [1.1–10])	28 (74% [57–87])	52 (53% [42–63])
N1-Southeast	3 (11)	5 (7.9)	4 (14)	1 (1.6)	20 (71)	33 (52)
N2-West	0 (0)	1 (5.9)	2 (29)	2 (12)	7 (100)	12 (71)
N3-Mid	0 (0)	0 (0)	0 (0)	0 (0)	1 (33)	5 (45)
N4-North	0 (0)	2 (25)	0 (0)	1 (13)	0 (0)	2 (25)
Sweden	8 (11% [5.0–21])	16 (8.4% [4.9–13])	20 (28% [18–40])	5 (2.6% [0.8–5.9])	49 (69% [57–79])	69 (35% [29–43])
S1-North	2 (29)	1 (6.7)	5 (71)	0 (0)	6 (86)	5 (33)
S2-Mid	2 (14)	0 (0)	2 (14)	1 (2.7)	10 (71)	16 (43)
S3-East	2 (9.1)	4 (8.2)	8 (36)	2 (4.1)	17 (77)	14 (29)
S4-West	1 (9.1)	2 (6.9)	4 (36)	1 (3.4)	4 (36)	10 (34)
S5-Southeast	1 (10)	1 (5.6)	1 (10)	0 (0)	8 (80)	10 (56)
S6-South	0 (0)	8 (18)	0 (0)	1 (2.1)	4 (57)	14 (30)
Nordic countries, total	17 (12% [7.1–18])[c]	28 (7.9% [5.3–11])[c]	45 (27% [20–34])	25 (5.3% [3.4–7.7])	108 (70% [67–82])[c]	147 (41% [36–46])[c]

Note: BPD: O_2 or any mechanical respiratory pressure support at postmenstrual age of 36 weeks and 0 days. Survivors at hospital discharge (Denmark, Iceland, Norway), up to 42 weeks of postmenstrual age (Finland), or to 1 year of age (Sweden).

[a]95% confidence intervals for proportions are presented for countries.

[b]The proportions with BPD and to some degree IVH/PVL may be underestimated because of incomplete reporting to the Danish National Patient Registry.

[c]Excluding Denmark because of incomplete data.

to varying birth rates at the lowest GA range.[30] Except for stratification for GA, neonatal morbidity and in-hospital mortality were not adjusted for case-mix.

The strengths included the nationwide, population-based design and up-to-date data from all five countries. Comparing capacity and practice in different Nordic regions increased granularity and disclosed more and larger variations than comparing national averages alone. Organisation of care does not change rapidly over time and should not be subject to random variation. Although used and analysed retrospectively, all data were prospectively collected by standardised definitions and procedures. The dataset included infants with congenital anomalies.

In conclusion, the organisation of care and management of very preterm infants exhibited significant regional variations in the Nordic countries. The identification of such variations in otherwise comparable settings could help to improve quality of care, guide further research and empower families.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to disclose.

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SUPPORTING INFORMATION

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