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Dutch Neonatal Intensive Care Nurses' Perceptions of Pulse Oximeter Saturation Target Limits for Preterm Infants

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ABSTRACT

Purpose: To conduct a national survey to assess practice, knowledge, barriers, and perceptions regarding oxygen saturation (SpO_2) target limits among Dutch neonatal intensive care unit (NICU) nurses.
Design and methods: Cross-sectional, web-based survey among 667 nurses from 9 level 3 Dutch NICUs. Part of the questions were based on a clinical scenario (28-weeks preterm infant, treated with CPAP, FiO_2 0.4).
Results: 328 (53.6%) nurses responded to the survey. Of these, 281 (85.7%) reported to know the local policy of SpO_2 target limits, and 261 (79.6%) and 244 (74.4%) rightly identified the lower and upper limit, respectively. Six NICUs recently increased their lower SpO_2 limit and for 62.0% of their nurses this led to a significant alarm increase. For the majority of the respondents, the baby from the clinical scenario would spend <10% of the time outside the lower or upper SpO_2 limits. Automated oxygen control systems were considered a good idea by 59.2% of the respondents, but 53.9% considered allowing parents to participate in FiO_2 titration a bad or very bad idea.
Conclusions: The majority of the respondents identified their unit's policy-specified SpO_2 target limits and reported that the increase in SpO_2 target limits may have led to more alarms. Titration of FiO_2 is a part of care that respondents were reluctant to share with parents.
Practice implications: A potential increase in the number of SpO_2 alarms may lead to alarm fatigue. Although family-centered care philosophy is widely accepted across Dutch NICUs, there are still barriers to overcome.

Introduction

Oxygen saturation as measured by pulse oximetry (Spo_2) has become the standard, noninvasive continuous method to estimate arterial oxygen saturation in neonates and to guide oxygen therapy (Bizzarro, 2018; Nghiem et al., 2008; Sola et al., 2014; Vento, 2014). However, for preterm infants requiring supplemental oxygen, the optimum range of Spo_2 to minimize organ damage, without causing hypoxic injury, has been and still remains very controversial (Bizzarro, 2018; Sola et al., 2014).

Between 2005 and 2007, five randomized controlled trials (RCTs), known collectively as the Neonatal Oxygen Prospective Meta-analysis (NeOProM) collaboration, were conducted with the primary objective of comparing the risks of a lower (85%–89%) vs. a higher (91%–95%) Spo_2 target range on the composite outcome of death or major disability in infants born before 28 weeks' gestation (Askie et al., 2011; Askie et al., 2017; Askie et al., 2018; Stenson, 2016). These trials showed that the lower Spo_2 target range was associated with a higher risk of death and necrotizing enterocolitis, but a lower risk of retinopathy of prematurity (Askie et al., 2018). Publication of the results of the individual NeOProM trials RCTs generated an intense debate reflected in commentaries, editorials, reviews, and meta-analyses (Askie et al., 2017; Jobe, 2014; Lakshminrusimha, Manja, Mathew, & Suresh, 2015; Samiee-Zafarghandy, Saugstad, & Fusch, 2015; Schmidt, Whyte, & Roberts, 2014; Sola, 2015; Sola et al., 2014; Synnes & Miller, 2015) performed in advance of the publication of the prospectively designed meta-analysis of individual participant data in 2018 (Askie et al., 2018). Despite this debate practice changes in individual neonatal intensive care units (NICUs) and revisions of guidelines and recommendations began to emerge (Bizzarro, 2018; Huizing, Villamor-Martinez, Vento, & Villamor, 2017; Sweet et al., 2013). In a survey conducted in 2016 among 193 European NICUs, 81% reported a recent change in their policy of SpO_2 target limit (Huizing et al., 2017). The new implemented limits were 3 to 5% higher than the former limits (Huizing et al., 2017).

Maintaining SpO_2 within the intended target range is a major challenge in the care of very preterm infants due to a number of factors ranging from severity of lung disease to the logistic challenge of frequent FiO_2 titration in a busy NICU setting (Armbruster, Schmidt,

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Poets, & Bassler, 2010; Mitra, Singh, El-Naggar, & McMillan, 2018; Nghiem et al., 2008; van Zanten et al., 2017; van Zanten, Tan, van den Hoogen, Lopriore, & te Pas, 2015). In addition, alarm fatigue or desensitization may develop when frequent SpO_2 alarms sound, yet the events self-resolve before clinical action is needed (Johnson, Hagadorn, & Sink, 2017). Strict adherence to the desired range of SpO_2 target values is essential to avoid hypo- or hyperoxemia. To achieve this, nurses are the most important actors because they set and aim for compliance with oximeter alarm limits. Nurses' knowledge, opinions and perceptions greatly influence this compliance (Nghiem et al., 2008). During the last few years, the majority of the Dutch NICUs have changed SpO_2target values for very preterm infants (Huizing et al., 2017). These changes may have affected the number of alarms, the difficulty to titrate oxygen therapy, or the proportion of time that infants are within SpO_2 target range. However, how these changes are perceived by the Dutch NICU nurses has not been researched. We aimed to conduct a national survey to assess practice, knowledge, barriers, and perceptions regarding SpO_2 target limits among Dutch NICU nurses. We also asked their opinion about the participation of parents of NICU infants in the titration of oxygen supplementation.

Methods

The survey was approved by the local institutional review board. We contacted through email the head nurse (operational manager) of each of the 10 level 3 NICUs in the Netherlands asking them if they would be inclined to distribute a web-based survey on SpO_2 limits among the nurses of their NICU. In the Netherlands, registered NICU nurses follow a 2-year specialization program after the 4-year bachelor's degree in Nursing. Registered NICU nurses are responsible for monitoring vital physiological parameters, administration of medication and feeding, and titration of oxygen administration. Their skills include, among others, venipuncture, intravenous catheter insertion, or placement of nasogastric tubes. The 10 Dutch hospitals with a level 3 NICU are the following: Academic Medical Center (Amsterdam), Erasmus Medical Center (Rotterdam), Isala Hospital (Zwolle), Leiden University Medical Center, Maastricht University Medical Center, Maxima Medical Center (Veldhoven), University Medical Center Groningen, University Medical Center Nijmegen, VU University Medical Center (Amsterdam), and Wilhelmina Children's Hospital (Utrecht). All managers responded positively to our request. The survey was pretested with a group of 10 NICU nurses, and changes were made to improve the clarity of the questions. The survey was open between October 2016 and May 2017. The original Dutch version of the survey is available at Harvard Dataverse (https://doi.org/10.7910/DVN/KDVDSD). Nurses were asked to answer 31 questions that are depicted in Supplementary Tables 1–4. The first 5 questions related to general information, years of work experience, and load of work (Supplementary Table 1). Questions 6 to 14 asked about perception of alarms and knowledge of SpO_2 target limits (Supplementary Table 2). These questions were based on the following clinical scenario: *Guus was born preterm (gestational age 28 weeks). He is now one week old. He is supported with CPAP with a FiO_2 of 0.4 (40% oxygen).* Questions 15 to 25 investigated the attitude and behavior of nurses in case of SpO_2 alarms (Supplementary Table 3). Finally, questions 26 to 31 asked nurses' opinion on strategies to increase the compliance with SpO_2 target limits (Supplementary Table 4).

Only descriptive statistics were performed including frequency counts, percentages, mean and standard deviation (SD) as well as median and interquartile range (IQR) when appropriate.

Results

Although the 10 head nurses of Dutch NICUs agreed to distribute the survey, one NICU only provided 2 responses and was excluded from the analysis. In the other 9 NICUs, the survey was send to 612 nurses and 328 responded to it. The number of responses of each NICU is depicted in Table 1. In order to anonymize the results, a random identification number was assigned to each NICU. An 87.8% of the respondents were registered NICU nurses and a 61,6% had >10 years of experience in a NICU. The average number of working days per month was 13.5 (SD 7.2). The majority of the respondents (76.8%) cared for 2 NICU babies per shift.

Forty-seven respondents (14.3%) acknowledged that they did not know the SpO_2 target limits used in their NICUs. Of the 281 nurses that responded that they knew the limits, 20 (6.1%) incorrectly identified the lower limit and 37 (11.3%) incorrectly identified the upper limit (Table 1). As shown in Table 2, incorrect identification of the SpO2 target limits did not depend on the years of experience as NICU nurse.

When asked how many high SpO_2 alarms will be produced by the monitor of a preterm infant (gestational age 28 weeks, postnatal age 1 week) treated with CPAP (FiO_2 0.4), most respondents (49.1%) estimated 3–5 alarms per hour (Table 3). A similar percentage (53.1%) of nurses estimated 3–5 alarms of low SpO_2 in that clinical scenario (Table 3). Then they were asked about the percent of time that they considered that the patient from the clinical scenario would be below the lower SpO_2 limit or above the higher SpO_2. The majority of the respondents considered that this time would be <10% (Table 4).

In another set of questions, three scenarios were delineated for the example case (1. SpO_2 82%; 2. SpO_2 70%; 3. SpO_2 98%). The perceived reaction time of the respondents was lower for the hypoxia than for the hyperoxia alarms (Table 5). In addition, as shown in Table 5, there was a clear difference between the attention that was paid to high SpO_2 alarms than to low SpO_2 alarms. Following titration of FiO_2 after an alarm due to a SpO_2 of 98%, a 30.5% of the respondents intend to stay with the patient always or almost always. In contrast this percent increased to 78.0% by an alarm due to a SpO_2 of 82% and to 91.5% if the SpO_2 is 70% (Table 5).

As depicted in Table 1, the 9 NICUs changed their SpO_2 target limits over the last 10 years. These changes were confirmed by the head nurses of each NICU. Only in one case (NICU 2), the lower limit was decreased, whereas 6 NICUs increased their lower SpO_2 limit. When the nurses of these 6 NICUs were asked about their perception of the number of alarms of low SpO_2, a 62.0% considered that alarms had increased or had increased a lot (Table 1). In 5 NICUs the upper SpO_2 limit was increased (Table 1). When the nurses of these NICUs were asked about

Table 1
Rate of response to the survey and knowledge of SpO_2 target limits.

NICU	Respondents		Did not know the SpO_2 target limits		Gave an incorrect lower limit[c]		Gave an incorrect upper limit[c]		NICU SpO_2 target limits	
	n	%	n	%	n	%	n	%	Current	Former
All	328	53.6	47	14.3	20	6.1	37	11.3	–	–
1	46	85.2	12	26.1	1	2.2	1	2.2	88–94	86–94
2	42	47.8	9	21.4	0	0.0	2	4.8	85–93	88–93
3	44	60.3	1	2.3	11	25.0	13	29.5	88–96[a]	88-92
4	25	41.7	4	16.0	0	0.0	1	4.0	89–95	85–89
5	34	48.6	5	14.7	0	0.0	3	8.8	85–95	85–90
6	25	31.3	5	20.0	4	16.0	4	16.0	86–93[b]	80-92
7	19	25.3	1	5.3	0	0.0	1	5.3	90–95	85–95
8	56	96.6	6	10.7	3	5.4	9	16.1	90–95	86–93
9	37	68.5	4	10.8	1	2.7	3	8.1	90–95	85–95

Table covers questions 9 (Are you aware of the oxygen saturation limits for a 28-weeks preterm newborn in your NICU?) and 10 (Can you indicate the current oxygen saturation limits that are used at your NICU for 28-weeks preterm infants receiving supplemental oxygen?).

[a] Alarm limits (88–96) differ from the target values (92–95).

[b] Alarm limits (86–93) differ from the target values (90–92).

[c] Answers were counted as correct if the respondent gave the right target value or the right alarm limit.

Table 2
Experience as NICU nurse and knowledge of SpO_2 target limits.

NICU experience	Respondents		Did not know the SpO_2 target limits		Gave an incorrect limit	
	n	%	n	%	n	%
>5 years	248	75.6	35	14.1	52	21.0
<5 years	82	25.0	11	13.4	17	20.7
No answer	8	2.4	1	12.5	1	12.5

their perception of the number of alarms of high SpO_2, a 34.8% considered that alarms had increased or had increased a lot (Table 6).

In the final part of the survey, we asked about three proposed ways to increase the compliance with SpO_2 target limits: (i) guidelines for manual FiO_2 titration (van Zanten et al., 2017), (ii) automated oxygen control (Brogi, Cyr, Kazan, Giunta, & Hemmerling, 2017; Claure et al., 2011; Claure & Bancalari, 2009; Hutten et al., 2015; Mitra et al., 2018; Plottier et al., 2017; Van Zanten, Kuypers, Stenson, et al., 2017; Zapata, Gomez, Araque Campo, Matiz Rubio, & Sola, 2014), and (iii) participation of the parents in manual adjustment of the FiO_2 (Martin-Pelegrina et al., 2018). We initially asked whether protocols for FiO_2 titration or automated oxygen control systems were available in their units. However, the responses to these two questions (26 and 30 of the original survey) were not analyzed because we were informed that, for some NICUs, implementation of titration protocols and/or automated oxygen control systems was ongoing at the time of the survey. When asked if parents were allowed to participate in manual adjustment of the FiO_2, only 2.1% of the respondents gave a positive answer and they specified that this happens only in exceptional circumstances. When asked their opinion about the above mentioned ways to increase the compliance with SpO_2 target limits, the majority of the respondents considered automated oxygen control systems potentially useful but they were more skeptical about the utility of guidelines for manual FiO_2 titration (Table 7). Finally, as shown in Table 7, parental participation in manual titration of FiO_2 was a scenario rejected by the large majority of the respondents.

Discussion

Poor compliance with the desired range of SpO_2 target values and with alarm limits for pulse oximetry is an important and common problem in NICUs worldwide (Armbruster et al., 2010; Hagadorn et al., 2006a, 2006b; Laptook, Salhab, Allen, Saha, & Walsh, 2006; Nghiem et al., 2008; Van Zanten et al., 2015). Staff education and creation of a culture of awareness about the detrimental effects of hypoxia and hyperoxia in very preterm infants (prompt response to alarms, root cause analysis at the bedside, and giving high priority to control of oxygen therapy) have been signaled as important determinants to achieve good compliance with the SpO_2 target values (Armbruster et al., 2010; Nghiem et al., 2008; Van Zanten et al., 2015; Van Zanten, Kuypers, Stenson, et al., 2017). Our survey showed that the majority of the Dutch NICU nurses identified their unit's policy-specified SpO_2 target limits. However 14.3% of the nurses who responded to the survey did not know the SpO_2 target limits used in their unit and 13% of those who reported knowing it identified different limits. This suggests that efforts should still be made to improve the level of knowledge and awareness about SpO_2 target values in Dutch NICUs.

Alarms in the NICU may number several hundred daily and that can lead to nursing desensitization and burnout, resulting in complacency toward alarm response (Johnson et al., 2017; Van Zanten et al., 2015). Alarm desensitization, or alarm fatigue, is a multifactorial problem related to the proliferation of alarming devices, use of alarm limits that are too narrow or not standardized, and the presence of false or non-actionable alarms (Johnson et al., 2017). In addition, the high burden of NICU alarms affects the ability of nurses perform their primary tasks in patient care, infant feeding, assessments, medication administration, or documentation (Johnson et al., 2017; Van Zanten et al., 2015). The majority of the nurses who responded to the survey estimated that a 28 weeks preterm baby supported with CPAP with a FiO_2 of 0.4 would have 6–10 alarms per hour and would be <5% of the time below and 5–10% of the time above the desired target of SpO_2. Interestingly, Van Zanten et al. showed in a systematic review on compliance in oxygen saturation that SpO_2 values are outside the target range between 20 and 70% of the time, when manual titration of oxygenation

Table 3
Expected number of SpO_2 alarms.

	n	%
High SpO_2 alarms per hour		
1–3	102	31.1
3–5	161	49.1
6–10	44	13.4
>10	11	3.4
No answer/don't know	10	3.0
Low SpO_2 alarms per hour		
1–3	53	16.2
3–5	174	53.1
6–10	75	22.9
>10	16	4.9
No answer/don't know	10	3.1

Table covers questions 6 and 7 which were based on the following scenario: Guus was born preterm (gestational age 28 weeks). He is now one week old. He is supported with CPAP with a FiO_2 of 0.4 (40% oxygen). How many alarms due to high saturation do you expect to respond to on average per hour, in an infant such as the one in the described case? How many alarms due to low saturation do you expect to respond to on average per hour, with such preterm infant?

Table 4
Estimated percent of time outside SpO_2 target limits.

Estimated percent of time	Below lower SpO_2 limit		Above higher SpO_2 limit	
	n	%	n	%
<5%	99	35.1	66	23.4
5–10%	90	31.9	103	36.5
10–20%	35	12.4	53	18.8
20–30%	20	7.1	26	9.2
>30%	1	0.4	5	1.8
No answer/don't know	37	13.1	29	10.3

Table covers questions 24 and 25 which were based on the following scenario: Guus was born preterm (gestational age 28 weeks). He is now one week old. He is supported with CPAP with a FiO_2 of 0.4 (40% oxygen). What percentage of a shift do you think the saturation of a preterm infant like Guus is too low? What percentage of a shift do you think the saturation of a preterm infant like Guus is too high?

Table 5
Estimated reaction time and behavior following alarms.

		SpO_2 82%		SpO_2 70%		SpO_2 98%	
		n	%	n	%	n	%
Reaction time:	<30 s	102	36.2	210	74.5	36	12.8
	30–60 s	126	44.7	44	15.6	129	45.7
	1–3 min	31	11.0	5	1.8	75	26.6
	3–5 min	3	1.1	2	0.7	17	6.0
	>5 min	0	0.0	0	0.0	4	1.4
	No answer	20	7.1	21	7.4	21	7.4
Stay with patient	Always	99	35.1	198	70.2	31	11.0
	Almost always	121	42.9	60	21.3	55	19.5
	Sometimes	40	14.2	4	1.4	119	42.2
	Almost never	1	0.4	0	0.0	48	17.0
	Never	1	0.4	0	0.0	6	2.1
	No answer	20	7.1	20	7.1	23	8.2

Table covers questions 15 to 23. Three scenarios were delineated: alarm related to oxygen saturation of 82%, 70%, and 98%. Nurses were asked about their estimated reaction time to the alarm and their behavior following the adjustment of FiO_2.

Table 6
Perception of number of alarms in relation to new SpO_2 target limits.

Perception	Increased a lot		Increased		Stayed the same		Decreased		Decreased a lot		No answer/Do not know	
	n	%	n	%	n	%	n	%	n	%	n	%
Low SpO_2 alarms	25	13.6	89	48.4	24	13.0	5	2.7	1	0.5	40	21.7
High SpO_2 alarms	15	8.2	49	26.6	50	27.2	11	6.0	0	0.0	59	32.1

Table covers questions 13 (Do you think the average number of monitor alarms for low saturation during a shift to which you have to respond has changed after the change in oxygen saturation limits?) and 14 (Do you think the average number of monitor alarms for high saturation during a shift to which you have to respond has changed after the change in oxygen saturation limits?).

is used (Van Zanten et al., 2015). Therefore, the results of our survey suggest that Dutch nurses underestimate the time that infants are outside the desired range of SpO_2.

All studies in compliance in SpO_2 targeting reported that maintaining the SpO_2 below the upper limit was the most difficult task (Arawiran, Curry, Welde, & Alpan, 2015; Claure et al., 2011; Claure & Bancalari, 2009; Clucas, Doyle, Dawson, Donath, & Davis, 2007; Hagadorn et al., 2006a, 2006b; Hallenberger et al., 2014; Lim et al., 2014; Mills, Davis, Donath, Clucas, & Doyle, 2010; Sink, Hope, & Hagadorn, 2011; van der Eijk, Dankelman, Schutte, Simonsz, & Smit, 2012; Van Zanten et al., 2015; Zapata et al., 2014). This fact is recognized by the majority of the respondents of our survey. Finally, Dutch nurses reported a longer response time to hyperoxia alarms than to hypoxia alarms. Moreover, the majority of the respondents acknowledged that they frequently did not stay with the patient after a high SpO_2 alarm. Altogether, these responses appear to confirm the speculation of van Zanten et al. that caregivers may be more accustomed to preventing hypoxemia than hyperoxemia (Van Zanten et al., 2015).

In the last years, the majority of European NICUs, including the Dutch ones (see Table 1), have changed their SpO_2 target limits (Huizing et al., 2017). A 75.3% of the respondents of the survey were aware of the changes in SpO_2 target limits which had been made in their NICUs. The new limits are higher and in the majority of cases the range is narrower (Huizing et al., 2017). Complying with these new ranges could be challenging for the NICU nurses and it has been reported that a narrower target range leads to a marked increase of SpO_2 alarms (Ketko, Martin, Nemshak, Niedner, & Vartanian, 2015). Accordingly, a 47% of the respondents considered that the new lower limits induced an increase in the number of alarms, whereas a 29.3% found that the new upper limit increased the number of alarms. As discussed above, excessive exposure to alarms can affect response from nurses and lead to alarm fatigue, which is potentially harmful to patients (Johnson et al., 2017; Ketko et al., 2015; Van Zanten et al., 2015; Van Zanten, Kuypers, Stenson, et al., 2017).

In the last part of the survey we asked the opinion of Dutch NICU nurses about three proposed ways to increase the compliance with SpO_2 target limits: (i) guidelines for manual FiO_2 titration (van Zanten et al., 2017), (ii) automated oxygen control (Brogi et al., 2017; Claure et al., 2011; Claure & Bancalari, 2009; Hutten et al., 2015; Mitra et al., 2018; Plottier et al., 2017; Van Zanten, Kuypers, Stenson, et al., 2017; Zapata et al., 2014), and (iii) participation of the parents in manual adjustment of the FiO_2 (Martin-Pelegrina et al., 2018). The majority of the respondents considered that the implementation of automated oxygen control systems would improve the compliance with SpO_2 target limits. In contrast, they were more skeptical about the utility of guidelines for manual FiO_2 titration. Finally, as discussed below, parental participation in manual titration of FiO_2 was a scenario rejected by the large majority of the respondents.

Table 7
Opinion about three strategies to increase the compliance with SpO_2 target limits.

Impact	Protocol for titration		Parental involvement		Closed loop system	
	n	%	n	%	n	%
Very negative	2	0.7	36	12.8	2	0.7
Negative	13	4.6	116	41.1	26	9.2
Neutral	109	38.7	69	24.5	58	20.6
Positive	68	24.1	26	9.2	140	49.6
Very positive	5	1.8	7	2.5	27	9.6
No answer	85	30.1	28	9.9	29	10.3

Table covers questions 27, 29, and 31: What effect/impact would have the three proposed ways to increase the compliance with SpO_2 target limits on your work?

Family-centered care is a philosophy that embraces a partnership between staff and families, and in which parents are considered a core member of their baby's care team (Coyne, 2015; Feeg & Shields, 2018; Ketko et al., 2015; Kuo et al., 2012; Martin-Pelegrina et al., 2018; Pallas-Alonso et al., 2012; Piris-Borregas et al., 2018; Smith, 2018; Wigert, Hellström, & Berg, 2008). Taking an active part in the care of their infant in a NICU helps parents to maintain a feeling of control over the situation, thus strengthening their parental identity (Bruce & Ritchie, 1997; Martin-Pelegrina et al., 2018; Pallas-Alonso et al., 2012; Piris-Borregas et al., 2018; Wigert et al., 2008). In addition, parents' contribution to the care of their child may be critical when nurses are busy or short-staffed (Coyne, 2015). Family-centered care has become a central feature in neonatal health care worldwide, but nurses and other staff caregivers have often difficulty with implementation of this philosophy because of lack knowledge and skills, role stress, negotiation failure, and power struggles (Bruce & Ritchie, 1997; Coyne, 2015; Dall'Oglio et al., 2018; Feeg & Shields, 2018). Therefore, although the ideas of parental participation in care are widely accepted within NICUs, their translation into specific policies and practices varies both within and between countries (Alsop-Shields, 2002; Coyne, 2015; Dall'Oglio et al., 2018; Feeg & Shields, 2018; Frost, Green, Gance-Cleveland, Kersten, & Irby, 2010; Jolley & Shields, 2009). In addition, while professionals expect parents to participate in basic child-care activities, they remain frequently reluctant to allow parents to assume more "technical" duties (Johnson et al., 2017). Manual adjustment of the FiO_2, in accordance with instructions from the staff, is one of the tasks that can successfully be performed by parents in the NICU (Martin-Pelegrina et al., 2018). However, our survey shows that Dutch NICU nurses are reluctant to delegate this task to the parents. An ongoing randomized controlled trial is aimed at determining whether saturation control by parents in very preterm infants increases the time in which infants remain at optimal saturation range when compared with conventional care performed by nurses (https://clinicaltrials.gov/ct2/show/NCT02306317). The results of this trial together with the increased experience in sharing care with parents might convince Dutch NICU nurses that parent involvement in the control of the FiO_2 is safe and could provide nurses with more time to perform more complex tasks. Nevertheless, it should be considered that, as assessed by Coyne, "family-centered care that arises from necessity rather than choice is in direct conflict with the overarching philosophy" (Coyne, 2015).

Limitations

There were a number of limitations to this study. We relied on respondents' own reports of behavior and attitudes. Despite being anonymous, respondents may have provided more socially acceptable

responses for fear of identification (Evans et al., 2006). In addition, although the response rate was acceptable, we cannot exclude the possibility of nonresponse bias (Kotaniemi et al., 2001) related to the cognitive burden of the survey and the potential differences in knowledge and/or motivation between respondents and nonrespondents. If nonresponse bias is a significant factor, we would expect it to skew our results toward more positive attitudes and higher level of knowledge and awareness regarding control of Spo_2 in preterm infants. Finally, there may be potentially important variables and barriers not included in the questionnaire because we needed to limit survey burden. Moreover, the survey did not include open questions which had allowed respondents to express their views, experiences and attitudes more freely.

Practice implications

A potential increase in the number of SpO_2 alarms may lead to alarm fatigue or desensitization, yet the events self-resolve before clinical action is needed. Oximeter alarms should be set to ensure care providers are alerted to potentially damaging high or low oxygen saturations while limiting non-actionable alarm proliferation (Johnson et al., 2017). Finally, regarding parental participation in NICU care, and although family-centered care philosophy is widely accepted across Dutch NICUs, we detected that there are still barriers to overcome. These barriers appear to particularly affect the participation of parents in more 'technical' aspects of care.

Conclusions

We detected a high level of awareness and knowledge about control of Spo_2 in preterm infants among Dutch NICU nurses but also concerns on the high alarm burden associated with the Spo_2 target limits.

CRediT authorship contribution statement

Maurice J. Huizing: Conceptualization, Data curation, Formal analysis, Project administration, Software, Writing - original draft, Writing - review & editing. **Eduardo Villamor-Martínez:** Data curation, Formal analysis, Software, Writing - original draft, Writing - review & editing. **Stefanie Meus:** Data curation, Project administration, Writing - review & editing. **Fred M. de Jonge:** Data curation, Project administration, Writing - review & editing. **Eduardo Villamor:** Conceptualization, Formal analysis, Supervision, Writing - original draft, Writing - review & editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pedn.2019.08.005.

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