Can Changes in Clinical Practice Decrease the Incidence of Severe Retinopathy of Prematurity in Very Low Birth Weight Infants?

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ABSTRACT. Objective. A wide variability in the incidence of severe retinopathy of prematurity (ROP) is reported by different centers. The altered regulation of vascular endothelial growth factor from repeated episodes of hyperoxia and hypoxia is 1 important factor in the pathogenesis of ROP. Strict management of O2 delivery and monitoring to minimize these episodes may be associated with decreased rates of ROP. The objective of this study was to compare the incidence of and need for surgery for severe ROP (stages ≥3) in infants of 500 to 1500 g birth weight before and after the implementation of a new clinical practice of O2 management in a large level 3 neonatal intensive care unit (NICU).

Methods. An oxygen management policy that included strict guidelines in the practices of increasing and weaning of fraction of inspired oxygen (FiO2) and the monitoring of O2 saturation parameters in the delivery room, during in-house transport of infants to the NICU, and throughout hospitalization was implemented in April 1998. The main objectives were to monitor oxygenation levels more precisely and to avoid hyperoxia and repeated episodes of hypoxia-hyperoxia in very low birth weight infants. Included in the policy were equipment for monitoring, initiation of monitoring at birth, avoidance of repeated increases and decreases of the FiO2, minimization of “titration” of FiO2, modification of previously used alarm limits, and others. After an educational process, each staff member signed an agreement stating understanding of and future compliance with the guidelines. Examinations were performed by experienced ophthalmologists following international classification and American Academy of Pediatrics recommendations. ROP data from January 1997 to December 2002 for infants of 500 to 1500 g were analyzed as usual and also have been reported to Vermont Oxford Network since 1998.

Results. The incidence of ROP 3 to 4 at this center decreased consistently in a 5-year period from 12.5% in 1997 to 2.5% in 2001. The need for ROP laser treatment decreased from 4.5% in 1997 to 0% in the last 3 years.

Conclusion. We observed a significant decrease in the rate of severe ROP in very low birth weight infants in association with an educational program provided to all NICU staff and the implementation and enforcement of clinical practices of O2 management and monitoring. Although several confounders cannot be excluded, it is likely that differences in these clinical practices may be, at least in part, responsible for the documented intercenter variability in rates of ROP. Pediatrics 2003;111: 339-345; retinopathy of prematurity, oxygen, pulse oximetry, very low birth weight.

ABBREVIATIONS. ROP, retinopathy of prematurity; VEGF, vascular endothelial growth factor; VLBW, very low birth weight; NICU, neonatal intensive care unit; VON, Vermont Oxford Network; Fio2, fraction of inspired oxygen; SpO2, oxygen saturation levels as measured by pulse oximetry; AAP, American Academy of Pediatrics; RN, registered nurse; RT, respiratory therapist.

Known risk factors for retinopathy of prematurity (ROP) include prematurity and low birth weight. In addition, worsening ROP has been linked to severity of illness and extent of complications.1,2 Much has been described in the literature regarding the role of supplemental oxygen in the development of ROP.3-7

The altered regulation of vascular endothelial growth factor (VEGF) has been suggested as 1 of the factors in the pathogenesis of ROP.8,9 In premature infants, the retina is incompletely vascularized. In utero, the arterial oxygen pressure of the fetus is 22 to 24 mm Hg. After premature birth, relative hyperoxia may downregulate VEGF production. Administration of supplemental O2 may lead to sustained hyperoxia, setting the stage for vaso-oblitration of existing vessels and arrest of the vascularization. Over time, as the metabolic demands of the developing eye increase, the immature nonperfused area of the retina becomes hypoxic and may overproduce VEGF pathologically. High levels of VEGF stimulate neovascularization of the retina, which in severe cases may result in retinal fibrosis and retinal detachment (Fig 1). It is thus possible that repeated cycles of hyperoxia and hypoxia favor the progression of ROP.10,11

With the improved survival of very low birth weight (VLBW) infants during the past decade, ROP continues to be a source of significant morbidity. Wide intercenter variability exists in the incidence of severe ROP (stage ≥3), with interquartile ranges between 4% and 18% in different centers.1,2,12,13 These differences could be attributed to the combination of many known and unknown factors; 1 explanation

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might be that differences in clinical practices affect the rates of ROP.

In our level 3 neonatal intensive care unit (NICU), data from 1997 and before showed elevated rates of severe ROP and the need for surgical treatment in comparison with data reported by the Vermont Oxford Network (VON; quartile ranges), publications that show lower rates in similar groups, and centers where authors had previously worked, particularly for infants with birth weight <1250 g. Therefore, a continuous quality improvement process, including an educational program and a new policy for O₂ delivery and monitoring, was implemented at our center in 1998 to address the strict management of O₂ in all VLBW infants (Appendix). The main goal was to minimize repeated episodes of alternating hypoxia/hyperoxia by modifying the practice of wide fraction of inspired oxygen (FIO₂) adjustments made in response to transient (and/or artifactual) readings on the oxygen saturation monitors and to avoid undesired episodes of high oxygen saturation levels as measured by pulse oximetry (SpO₂). The policy addressed equipment to be used for monitoring, acceptable SpO₂ parameters; alarm settings and clinical responses to alarms; bedside care after increasing FIO₂; and the careful regulation of FIO₂ in the delivery room, during transport to the NICU from the delivery room, and throughout the entire course in the NICU (Appendix). The purpose of this report is to describe the incidence of severe ROP (stage ≥3) and laser therapy for ROP in VLBW infants (birth weight 500-1500 g) before and after the implementation of these practice changes at our level 3 NICU.

**METHODS**

This is a clinical descriptive study in which data were collected during a 5-year period (January 1997–December 2001) in a single tertiary neonatal center. Data were collected prospectively in real time and stored in the local database; for 1998 to 2001, they were also submitted to the VON, using their usual data collection forms. The VON is a nonprofit voluntary collaboration of >400 NICUs in North America, Europe, the Middle East, Asia, and the Pacific Rim that, among other efforts, includes a low birth weight database. The database is an independent and neutral source of information regarding clinical practices and outcomes for high-risk infants and is used for providing unique, comprehensive, individualized and confidential reports to participating neonatal units. The database includes >25,000 infants, and this number changes year by year. A large number of these infants are screened for ROP; we used the same methods to calculate the rates of severe ROP and therapy as used by the VON (see later).

The infants were examined by the same pediatric ophthalmology service, following ROP international classification and American Academy of Pediatrics (AAP) guidelines. Data are reported for VLBW inborn infants, as the number of outborn infants was minimal for this birth weight group and did not contribute to the number of cases of severe ROP or of cases of ROP requiring surgery. The data were collected and analyzed in different birth weight categories (500–749 g, 750–999 g, 1000–1249 g, and 1250–1500 g). The rates of severe ROP (stages ≥3) were calculated using the number of cases of severe ROP diagnosed as the numerator and the total number of infants who received retinal examinations as the denominator. For calculating the rates of laser therapy, the number of infants who underwent therapy is used as the numerator. Furthermore, the percentage of infants screened (n screened/n eligible for screening ×100) was monitored through the years. For presentation in the figures, we elected to use the rates calculated as described, as opposed to using actual numbers. The absolute numbers in the VON database are very discrepant from the ones at an individual center; we therefore chose to present the rates defined and calculated in the same way to make visual comparison easier. Data collected also included gender, race, infection, prenatal steroid administration, transfusion practices, and use of postnatal steroids, among others.
nally, data regarding survival rates were also collected and analyzed for this same period. The mortality rate includes all deaths at any age that occurred before discharge from the NICU.

Eye drops were performed by pediatric ophthalmologists. Between January 1998 and December 2001, the same 3 ophthalmologists screened the infants and a dedicated registered nurse (RN) was also hired to ensure that all eligible infants had eye examinations at the appropriate time according to AAP guidelines. Eye drops to dilate the pupils (Cyclopentolate and Mydriacyl 0.5%, Alcon, Dallas, TX, 1 drop to each eye × 2 instilled 5 minutes apart) were administered by the bedside RN 1 hour before examination. The examination was done by indirect ophthalmoscopy, with an eyelid speculum in place and with gentile scleral depression. After discharge, developmental assessment was performed in our Infant Progress Clinic, and ophthalmological follow-up was performed by 2 of the ophthalmologists.

The policy for O2 monitoring and administration for VLBW infants at birth and during their first few weeks of life was implemented in April 1998 (Appendix). The main objectives were to monitor oxygenation levels more precisely to attempt to decrease the numbers of “false alarms” and to avoid hyperoxia and repeated episodes of hypoxia-hyperoxia in VLBW infants. Included in the policy was new equipment for monitoring SpO2 to measure more accurately arterial blood oxygen saturation levels and pulse rates in the presence of the infant’s movement and low perfusion17 (Masimo Radical Signal Extraction Technology Pulse Oximeter, Irvine, CA). Other aspects of the policy included initiation of monitoring during in-hospital transport, and duration of the unit procedure and avoidance of repeated increases and decreases of the FiO2, minimization of “titration” of FiO2, modification of previously used alarm limits, and others (Appendix). The process also included the development and establishment of the “CRADLE Club” (Caring, Responsible Approach to Development in the Lives of Extremely low birth weight infants), which included a specialized designated care group of neonatal nurses and neonatal respiratory therapists. These individuals were specifically assigned as leaders of care teams and/or as direct care providers, participating actively in the continuous and timely care of these tiny newborn infants. An in-depth staff educational process for doctors, respiratory therapists (RTs), RNs, and housestaff. The goal of the policy was to curtail unnecessary O2 use and administration, to minimize abrupt changes in FiO2, avoid periods with SpO2 >93% to 95%, and prevent large swings in O2 saturation. The saturation goal limits chosen for treatment of VLBW infants at our center were based on physiologic principles and the known relationship between PaO2 and oxygen saturation in newborn infants18,19 and were used in the delivery room, from the moment of birth, until 2 to 8 weeks of age, depending on gestational age at birth. Accepted values in SpO2 were from 85% to 95% for infants >32 weeks’ gestation and 85% to 93% for those <32 weeks’ gestation. In addition, saturation limits of 83% to 93% were adapted with the discretion of the attending neonatologist for the smallest, highest risk infants. In accordance with this policy, alarms are not to be turned off or changed after increasing FiO2. When and if FiO2 needs to be adjusted, both the infant and the monitor are to be evaluated. Weaning of FiO2 is required when the SpO2 is on the “high” side or above the desired range. This weaning could be done as quickly as necessary but decreasing FiO2 by not >2% to 5% at a time to avoid sustained hyperoxia while at the same time decreasing the likelihood of episodes of subsequent “unexpected” hypoxia. When there is a need to increase the FiO2, the nurse or RT who increases the FiO2 remains at the bedside until the infant is adequately assessed, the SpO2 is within the desired range, and the new FiO2 requirement is fully documented, with the objective to avoid subsequent hypoxic episodes. If to maintain the infant’s saturation within the preestab-

### RESULTS

The number of inborn infants admitted to the NICU with birth weights 500 to 1500 g was fairly stable through the years, varying from 86 to 92 per year (Table 1). Rates of survival until the time of discharge by birth weight and by year are also summarized in Table 1. Survival rates showed a trend toward improvement for the whole group, especially for infants with birth weight of 500 to 749 g. In addition, the percentage of infants screened (data not shown) improved in 1998 and has been 100% for 1999 to 2001.

After the O2 policy implementation in 1998, the incidence of ROP stages 3 to 4 for all infants <1500 g decreased from 12.5% to 2.5% between 1997 and 2001 (Fig 2). This figure also shows the global incidence reported by the VON for the same period, which has not changed significantly in the same time period. Figure 3 depicts the percentage of infants who survived without severe ROP at our center (76% in 1997 and 88% in 2001.)

In Fig 4, the incidence of severe ROP (stages 3–4) at this center is shown by birth weight category. The rate for ROP stages 3 to 4 in infants of 500 to 749 g was 38% before the implementation of the policy and has decreased to 10% to 12% in 2000 to 2001. In addition, the rates of severe ROP decreased significantly in infants with birth weight of 750 to 999 g (12%–15% in 1997 and 1998 to no severe cases in the past 3 years), similar to what occurred for infants of 1000 to 1249 g between 1997 and later. For infants with birth weight of 1250 to 1500 g, the rates were very low before implementing the practice change and there have been no severe cases of ROP since 1998.

### TABLE 1. Survival Rates

<table>
<thead>
<tr>
<th>Birth Weight (g)</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>% Surive</td>
<td>% Survive</td>
<td>% Survive</td>
<td>% Survive</td>
<td>% Survive</td>
<td>% Survive</td>
</tr>
<tr>
<td>500–749</td>
<td>14</td>
<td>48</td>
<td>15</td>
<td>40</td>
<td>18</td>
<td>73</td>
</tr>
<tr>
<td>750–999</td>
<td>25</td>
<td>74</td>
<td>27</td>
<td>78</td>
<td>18</td>
<td>84</td>
</tr>
<tr>
<td>1000–1249</td>
<td>24</td>
<td>88</td>
<td>20</td>
<td>100</td>
<td>26</td>
<td>96</td>
</tr>
<tr>
<td>1250–1500</td>
<td>29</td>
<td>97</td>
<td>27</td>
<td>100</td>
<td>26</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>92</td>
<td>81</td>
<td>89</td>
<td>83</td>
<td>88</td>
<td>85</td>
</tr>
</tbody>
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The incidence of ROP laser therapy for the whole group (Fig 5) was 4.4% in 1997 and decreased to 1.3% in 1998. Since December 31, 1998, 0% of infants have required laser therapy for ROP. Figure 5 also shows the operative rates as reported by the VON.

DISCUSSION

As part of an organized process of improvement in quality of care, the implementation of a clinical practice change of curtailed O₂ was associated with an important and clinically significant decrease in the incidence of both severe ROP and the need for ROP therapy. The greatest change was in infants with birth weight between 500 and 999 g, with virtual elimination of severe ROP in the 750- to 999-g birth weight category. In these most immature infants, the area of avascular retina is the largest and is subject to periods of relative hyperoxia even while on room air.

In addition, these infants have longer, more complicated hospitalization with longer periods of assisted ventilation and oxygen supplementation, widely known comorbid conditions associated with worsening ROP. However, the decrease in the incidence of severe ROP was gradual, not abrupt. We speculate that this was attributable to several factors, which included resistance to change and difficulties in achieving consistent implementation of the management of monitors and oxygen in all shifts at all times. This was attributable to “nonuniform” acceptance of staff. This made us provide training, retraining, education, and sharing of evidence as an ongoing process. Even then, witnessing lack of compliance by some staff, we requested a signed statement by all personnel in the NICU, acknowledging understanding of the policy and the mandate to comply. Only then was the gap between the policy and the practice minimized or eliminated. We can speculate that the decrease in incidence of ROP was “gradual” because the change in practice was also gradual, as a result of the time that it took for the “buy in” of all bedside nurses and RTs to deliver the practice at all times for all infants. In addition, many care providers reported greater ease in following the policy with the use of new SpO₂ monitors (Masimo Signal Extraction Technology) with less artifact and fewer false low alarms.

The visual prognosis for children who have ROP and reach threshold disease is poor, despite available current medical interventions. The multicenter cryotherapy study showed that approximately 30% of the infants who had threshold disease and received cryotherapy still had unfavorable vision at 3-month follow-up, and similar results were seen at 1-year, 5.5-year, and 10-year follow-ups. Although laser therapy is an accepted therapy for threshold ROP, reducing threshold disease is the main goal to avoid unfavorable visual outcomes. In our population, we observed that, since January 1999, no infant among 238 surviving infants with birth weight <1500 g and 148 surviving infants with birth weight 500 to 1250 g reached threshold disease or required laser therapy.

In the recent multicenter STOP-ROP trial, SpO₂ target was higher (96%–99%), but patients who were entered into this trial had already reached prethreshold ROP. The study findings concluded that the use of supplemental O₂ did not cause the progression of
prethreshold ROP but did increase the risk of other systemic complications. As discussed by Hay and Bell, it would be a misconception to assume from the STOP-ROP study that it could be safe or acceptable for preterm infants to undergo liberal oxygen administration during the early phases of their neonatal course, in the early periods of retinal vascularization (ie, before reaching prethreshold disease).

The guidelines for saturation goal limits for treatment of VLBW infants at our center (SpO₂ from 85% to 95% for infants ≥32 weeks’ gestation, from 85% to 93% for those ≤32 weeks’ gestation, and from 83% to 93% in some cases based on the discretion of the neonatologist) were based on the lack of evidence to support the need of SpO₂ >95% to 98% and on references cited in “Methods.” However, we acknowledge that there are no well-established data for such recommendations and that different SpO₂ monitors do not measure exactly the same values of saturation under the same conditions in the same infant, particularly during motion or low perfusion states.

Recently, Tin et al compared whether differing policies on the control of oxygen saturation had any impact on the number of infants who develop ROP with or without signs of cerebral palsy. The authors found that infants who were given enough supplemental oxygen to maintain a saturation of 88% to 98% developed ROP that required cryotherapy 4 times as often as infants who were given enough O₂ to maintain oxygen saturation of 70% to 90%, whereas there was no change in the incidence of cerebral palsy between the groups. In our own center, we are still evaluating the long-term outcomes of infants who were treated aiming for lower oxygen saturation after the implementation of the protocol. Although none of the infants whom we treated were “truly hypoxic” (assumed as SpO₂ <75%) for any period of time using the new O₂ saturation limits of our policy, it is important to ensure that the long-term neurodevelopmental outcome is not adversely affected by using these new alarm limits. Although detailed developmental assessment to answer this question is in progress at our center, our preliminary information of infants born until mid-2000 does not show unfavorable effects. The developmental assessment is still being investigated, because infants who were born late in 2000 and in 2001 are not yet 18 months of postconceutional age. The rate of developmental disabilities (Bayley scale score Mental Development Index <70 or Psychomotor Development Index <70) and of cerebral palsy for the infants born in 1997 to June 2000 has not changed significantly during the study years (being approximately 17%), but there is a trend toward diminishing unfavorable outcomes (currently at 10%). On the basis of the neurodevelopmental findings in Tin’s report and in our preliminary findings, it is possible to speculate that maintaining even lower values of oxygen saturation than the ones we used could have been of more benefit for the infants with birth weight of 500 to 749 g in this study, in whom the rate of severe ROP improved to approximately 10% but has not decreased further since the year 2000.

The findings at our center do not provide sufficient evidence to support a cause and effect relationship between the described educational process, the change in clinical practice, and the decreased ROP rates. This is not a controlled, randomized study, and the duration of SpO₂ readings above or below pre-defined ranges was not accurately quantified for each infant in a concurrent manner in this study. In addition, the role of several confounders cannot be excluded in this descriptive study. However, some of the known factors involved in lower ROP rates can be excluded. For example, increased mortality rates in VLBW infants could cause an apparent decrease in ROP rates. The opposite occurred during the time period of this study, with overall improved survival rates (Table 1). In addition, lower ROP rates can be observed if the number of the infants at highest risk varies or if the survival rate for infants <750 g decreases. Again, the reverse was true in this study. In addition, a change in patient demographics, including gender, race, rate of infection, or blood transfusion practices, may be associated with varying rates of severe ROP. We carefully analyzed these factors in our own database and in the VON reports and found that no significant changes had occurred over time (data not shown). Finally, “falsely low” rates of severe ROP in a NICU can also be related to screening deficits or inaccuracies of the examination. A protocol for ROP screening examinations was implemented as of 1998 with dedicated pediatric ophthalmologists and RNs. All infants who met criteria based on AAP guidelines (=1500 g, oxygen exposure, or difficult postnatal course as determined by neonatologist) were examined while in the NICU, and outpatient follow-up was ensured when needed. We are confident that no infant with severe ROP and/or blindness has been missed since 1998.

Other changes in clinical practice that could also be associated with a change in ROP rates include the utilization rate of prenatal steroids; this has been and has remained at approximately 89% in our institution. Other potential confounders could be related to different ventilation strategies and to the use of postnatal steroids. At our institution, there was a decrease in the use of high-frequency oscillatory ventilation during these years (from 38% to 18%), but the partial arterial pressure of carbon dioxide and pH values were not examined specifically, so we cannot comment on their potential effect on the decreased rates of severe ROP observed. Between 1998 and 2000, the use of postnatal steroids in VLBW infants at our NICU decreased from 24% to 6%. This corresponds to the 42nd percentile in the VON in 1998 and the 9th percentile in 2000. Whether this change is partly involved in the decreased ROP rates remains to be understood. Some randomized studies have not shown an association between postnatal steroids and ROP, but a recent multiple regression analysis has shown an increase in the rate of ROP associated with the use of postnatal steroids.

Without ignoring the effects of potential confounders or the increasing survival rates of the tiniest infants, we think that the new motion and low perfusion tolerant pulse oximeter (Masimo Signal Ex-
traction Technology), the staff education and increased awareness related to $O_2$ administration and monitoring, and the objective to avoid $SpO_2 > 93\%$ to 95% played a positive role in the decreasing rates of severe ROP observed. The steps included a detailed and lengthy educational process and the buy in of care providers, ensuring universal implementation. We attribute this to many factors, including learning behavior and reinforcement of practices over time, clinical competence of caregivers, and the development and implementation of a specialized designated care group of neonatal nurses and neonatal RTs specifically for tiny infants. We consider that the clinical significance of these changes in 1 center is high, but we acknowledge that the association of other factors may also have played a significant role in the improved outcomes in ROP.

CONCLUSION

The rate of severe ROP and the need for laser therapy for severe ROP can decrease significantly in association with the use of adequate pulse oximetry monitoring equipment and the implementation of a strict clinical practice of oxygen administration and management in infants with birth weight of 500 to 1500 g. The findings of this report lend support to the assumption that some of the intercenter variability described for ROP rates is related to differences in clinical practices and could be related, at least in part, to the differences in the minute-to-minute handling of $O_2$ administration and monitoring.

APPENDIX: MANAGEMENT OF $FiO_2$ AND OXYGEN SATURATION MONITORS IN VLBW INFANTS

(Policy originally prepared by Augusto Sola, MD, on March 12, 1998)

Objective of this policy: To avoid hyperoxia and repeated episodes of hypoxia-hyperoxia in VLBW infants (birth weight <1500 g).

The issues covered in this policy are to start at the time of birth and to be maintained at all times (ie, during “transition,” for diagnostic procedures, and in NICU). The pulse oximeter equipment (oxygen saturation monitor) to be used for these infants is Masimo Signal Extraction Technology.

1. No VLBW infant will be subject at any time to repeated increases and decreases of the $FiO_2$ in response only to the readings in the oxygen saturation monitors.

2. The $FiO_2$ will not be “titrated” (ie, changed frequently “up and down and up again”) to try to maintain the oxygen saturation monitor reading between “acceptable” levels.

The following issues related to oxygen, oxygen saturation monitors, and changes in $FiO_2$ are to be understood and implemented in daily practice.

1. Oxygen is a drug: It could be a very dangerous medicine with potentially significant side effects in VLBW preterm infants. Avoiding hypoxia is important, but prolonged hyperoxia can lead to oxidative stress and injury. There is no evidence that VLBW infants need to be managed with an $FiO_2$ that leads to surface oxygen saturation levels ($SpO_2$) of 95% to 100%. Actually, these levels are potentially dangerous. In addition, repeated episodes of alternating hyperoxia/hypoxia can promote significant alterations in vascular tone in immature infants. By avoiding these episodes, risks to the developing vascular bed in various organ systems could be minimized.

2. Low oxygen saturation alarms: When an infant shows a low alarm for oxygen saturation (ie, $SpO_2 < 85\%$) both the infant and the monitor should be evaluated before any changes are made in $FiO_2$.
   a. Is the pulse wave appropriate?
   b. Is their motion artifact?
   c. How is the heart rate and respiratory effort?
   d. How low is the saturation and for what period of time has it been below acceptable values?

3. Alarm settings of oxygen saturation monitor: The monitor will be used immediately after birth. The usual alarm setting for low $SpO_2$ is 85% and for high $SpO_2$ is 95% (or up to 95% in larger VLBW infants). Settings should not be changed because the monitor alarm frequencies. The settings will never be changed after an increase in $FiO_2$. The alarms will not be turned off at any time.

4. Weaning $FiO_2$ and oxygen saturation.
   - $FiO_2$ can be weaned by 2% to 5% at a time if the oxygen saturation ($SpO_2$) is on the “high” side. In the delivery room, wean $FiO_2$ rapidly to avoid $SpO_2 > 93\%$. Maintain same plan during transport to NICU.
   - This “high” side of $SpO_2$ during the NICU stay has to be determined for each individual VLBW infant. (“High” is usually an $SpO_2 > 92\%$ for infants who are <1000-1100 g or <32 weeks of gestation and >94% for infants >1200 g or >32 weeks of gestation).
   - The weaning can be done as fast as necessary, to avoid periods of hyperoxia, but by no more than 2% to 5% at a time.
   - Exercise caution to avoid an exaggerated decrease in $SpO_2$ that can produce an undesired decrease in $SpO_2$ that could subsequently lead to hypoxia (and then a subsequent abrupt increase in $FiO_2$ with risk for hyperoxia.)
   - Weaning can usually be done as long as the oxygen saturation is stable and >92 to 95%. However, the oxygen saturation at which weaning will occur will be determined for every infant every morning at around 8:30 AM, jointly between MD/NNP and RT. Subsequently, a written order will be placed in the chart. If needed, this will be revised during the evening shift.

5. Charting: When the infant and the oxygen saturation have been stable at a certain weaned $FiO_2$ (for at least an hour), this is the $FiO_2$ that will be charted in the records, as the last stable $FiO_2$. This will then represent the $FiO_2$ that the infant requires to maintain normoxia (without exposure to frequent hyperoxia and/or hypoxia episodes).

6. Increases in $FiO_2$:
   - In every case that a VLBW infant requires an increase in $FiO_2$, the nurse or RT who made this change will not leave the bedside until the infant is adequately assessed and stable and appropriate documentation has been performed. This includes a stable $SpO_2$ within the desired ranges at a certain increased $FiO_2$. This will decrease the likelihood of a high $O_2$ saturation for any period of time after increases in $FiO_2$.
   - The nurse and RT will together make the decision as to whether an MD/NNP should also be notified when $FiO_2$ needs to be increased.
   - An MD/NNP must always be notified when it is necessary to keep the $FiO_2 > 5\%$ from the previous “stable” $FiO_2$ to maintain the infant’s oxygen saturation within the preestablished saturation range.

7. Oxygen desaturation after handling or a procedure (ie, airway suctioning): In these cases, instead of “simply” increasing the $FiO_2$, it may be more appropriate to transiently increase positive end-expiratory pressure or to use faster respiratory rates. (In some cases, it may be necessary to increase the peak pressure by 2 cm H$_2$O and to evaluate “lung volumes” clinically or with bedside monitoring.) NEVER increase $FiO_2$ >5% to 10% as the only action. It is Important to avoid hypoxia, but it is also important to avoid subsequent hyperoxia. (After suctioning, observe infant for at least 10 minutes, because adjustment of respiratory settings may be needed.)

8. Spontaneous oxygen desaturation: If the $FiO_2$ needs to be increased to avoid persisting and/or recurring oxygen desaturation in a short period of time, then the nurse and RT need to assess the infant appropriately. The RT will also assess ventilator function and/or oxygen delivery to the infant. Judgments should be made jointly by nurse and RT as to whether MD/NNP has to be notified to evaluate the need of changing ventilator settings and not only the $FiO_2$. A new order will then be written.

9. “Apneic” spells and oxygen desaturation: The adequate response is to increase respiratory rate, increase respiratory parameters, or use tactile stimulation and/or, in severe cases, manual ventilation. In general, with these steps, the same $FiO_2$ that the infant was receiving before the episode will be sufficient to promote recovery. If an infant needs “resuscitation,” then oxygen will be increased only when needed and MD/NNP notified immedi-
ately. A new \( \text{FiO}_2 \) order may be required after the significant episode.

In summary, for VLBW infants (birth weight <1500 g):

- Masimo Signal Extraction Technology oxygen saturation monitor
- No “titration” of \( \text{FiO}_2 \) (can produce dangerous and risky “ups and downs” in infant’s oxygenation levels).
- Important to wean actively (according to individual assessment).
- No increase in \( \text{FiO}_2 \) without assessing infant (and monitor).
- Every increase in \( \text{FiO}_2 \) requires careful assessment and documentation.
- Do not keep increased \( \text{FiO}_2 \) without additional assessment by MD/NNP. Changes in respiratory parameters may be necessary.
- The \( \text{FiO}_2 \) requirement of the infant should be documented clearly.
- Do not leave bedside if any changes in \( \text{FiO}_2 \) have been made.
- No infant should be left as stable if the condition had required an increase in \( \text{FiO}_2 \) >3% to 5%.

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