Techniques and Procedures

A Practical Guideline for Calculating Parenteral Nutrition Cycles

Chris Longhurst, MD, MS*; Louie Naumovski, MD, PhD†; Manuel Garcia-Careaga, MD‡; and John Kerner, MD‡

**Department of Pediatrics, †Division of Hematology-Oncology, Department of Pediatrics, and ‡Division of Gastroenterology and Nutrition, Department of Pediatrics, Stanford University, Stanford, California*

ABSTRACT: *Background:* Both physiologic and psychological reasons for cycling total parenteral nutrition (TPN) have been well established. Despite widespread acceptance of this practice, the only previously published method for calculating TPN cycle rates is inherently flawed. *Methods:* A mathematical formula was derived to facilitate reliable calculation of cyclic TPN flow rates as a function of total volume and cycle time. A publicly accessible website was subsequently developed to expedite rapid determination of TPN cycles. *Results:* A fail-safe method of calculating TPN cycle flow rates can be expressed as $F = V/(4T\text{-}10)$, where F is equal to the basal flow rate (mL/h), T is equal to the desired cycle time (hours), and V is equal to the total volume of TPN (mL) to be delivered in 24 hours. The basal flow rate and twice the basal flow rate are used for the first and last 2 hours of the TPN cycle, and the remainder of the cycle runs at 4 times the basal flow rate. TPN cycles may be easily calculated online using this formula at http://peds.stanford.edu/tpn.html. *Conclusions:* We have developed a fail-safe method of calculating TPN cycle flow rates that will consistently deliver the desired volume and have made an online implementation of this formula publicly available.

Cycling total parenteral nutrition (TPN) refers to the technique of infusing a daily solution in a <24-hour period of time. Theoretical advantages of cyclic TPN include prevention or treatment of TPN-induced fatty infiltration of the liver, prevention or treatment of essential fatty acid deficiency, more rapid restoration of albumin levels, prevention of the hyperinsulinism of continuous TPN, and prevention of lipogenesis (which can increase the respiratory quotient).[1] In 1994, Collier and colleagues[2] published a study in which they observed stabilization or improvement in direct bilirubin concentrations of 8 of 10 infants <6 months of age after initiating cyclic TPN. Several years later, Meehan and Georgeson[3] published the promising results of a retrospective analysis using cyclic TPN as part of a comprehensive protocol to prevent liver failure in parenteral nutrition–dependent children with short bowel syndrome. Even more recently, Hwang and colleagues[4] published a prospective, controlled trial in which they concluded that early TPN cycling prevented further deterioration of liver function in jaundiced patients who required prolonged parenteral nutrition support.

Although the initial impetus behind cyclic TPN as first described by Maini and coworkers[5] was to confer a physiologic advantage over continuous infusion, it is now well accepted that the psychological benefits are equally tangible for many patients. Freedom from the infusion apparatus allows for greater social activity and interaction, and children, in particular, may benefit from increased school attendance and the opportunity to participate in sports programs. Indeed, one of the earliest prospective studies of nocturnal TPN in hospitalized adults suggested that "a main satisfaction of the present technique was the appreciable comfort of the hospitalized patients" with subsequent improvement in morale and acceptance of treatment.[6]

The most important practical aspect of cycling TPN is calculating tapered flow rates so that glucose infusions are started and stopped slowly to prevent potentially harmful fluctuations in blood glucose. It is well known that hyperglycemia can be induced by the rapid initiation of TPN[7] and clinical experience with pediatric patients has shown that rebound hypoglycemia can occur with acute discontinuation, although the evidence in adult patients differs.[8,9] Given the substantial body of research supporting the use of cyclic TPN in appropriately selected patients, it is somewhat surprising that so few guidelines for calculating these TPN cycles exist.

The Old Method

To our knowledge, Faubion et al have published the only guideline for calculating TPN cycle flow rates,[10] and their method is referenced in several

Correspondence: John Kerner, MD, Pediatric Gastroenterology, Lucile Salter Packard Children's Hospital, 750 Welch Road #116, Palo Alto, CA 94304. Electronic mail may be sent to john.kerner@stanford.edu.

0884-5336/03/1806-0517$03.00/0
Nutrition in Clinical Practice 18:517–520, December 2003
Copyright © 2003 American Society for Parenteral and Enteral Nutrition

textbooks.[1,11,12] Unfortunately, this formula is inherently flawed and can cause patients to inadvertently receive an incorrect volume of nutrition support and therefore an incorrect amount of caloric support. The problem with the method they described is that flow rates are not calculated to deliver 100% of the desired TPN volume. Rather, the authors recommended calculating a peak infusion rate by dividing 90% of the total volume by the desired cycle time minus 4 hours, and the ramping rates are simply one-half and one-quarter of this peak flow rate. Therefore, whereas 90% of the TPN will always be delivered during the time of peak flow, either too much or too little volume may be administered during the remainder of the infusion.

When the Faubion method is mathematically deconstructed (data not shown), it becomes clear that the percent of introduced error varies inversely with the cycle time and independently of the desired cycle volume (Fig. 1). In fact, flow rates calculated using this method will deliver the correct volume only at a cycle time of exactly 17½ hours. If the calculated flow rates are precisely administered, TPN cycles longer than 17½ hours will always deliver too little TPN (2.5% less in a 22-hour cycle), and shorter cycles will always result in a greater volume administered than desired (6.9% more at 12 hours and 23.8% more at 8 hours). For example, a 5-kg infant receiving 120 mL/kg/day of TPN cycled over 12 hours would receive 641 mL of TPN per day rather than the desired 600 mL. It is conceivable that such an error could become clinically significant over several days, depending on the patient's underlying condition and the length of therapy.

A New Method

We have developed a more reliable method of calculating cyclic TPN flow rates for the patients of Lucile Packard Children's Hospital at Stanford University. An abstract TPN cycle was conceived such that the total desired volume is delivered at a basal rate during the first and last hour of the cycle, twice that rate during the second and penultimate hour, and 4 times the basal rate during the remainder of the cycle. Because the product of the basal flow rate (F) and the time spent flowing at that rate yields the volume delivered in that time, given any total cycle time (T), we can express the total TPN volume (V) of that cycle as:

$$V = 1F + 2F + 4F(T - 4) + 2F + 1F$$

Solving for the basal flow rate, our equation becomes:

$$6F + 4F(T - 4) = V$$

$$6F + 4FT - 16F = V$$

$$4FT - 10F = V$$

$$F(4T - 10) = V$$

$$F = V/(4T - 10)$$

Thus the basal flow rate of any TPN cycle can be calculated by dividing the total volume to be delivered by the sum of 4 times the total cycle time minus 10 (Fig. 2).

Suppose a patient requires TPN with a total volume of 1400 mL per day. Although this amount would typically be delivered at 58.3 mL/h continuously, if the same volume is to be cycled over 20 hours, our equation yields a basal flow rate of 20 mL/h. Therefore, the TPN should flow at 20 mL/h during the first and last hour, 40 mL/h during the second and penultimate hour, and 80 mL/h during the remaining 16 hours. Similarly, the same volume administered over a 12-hour cycle will flow at rates

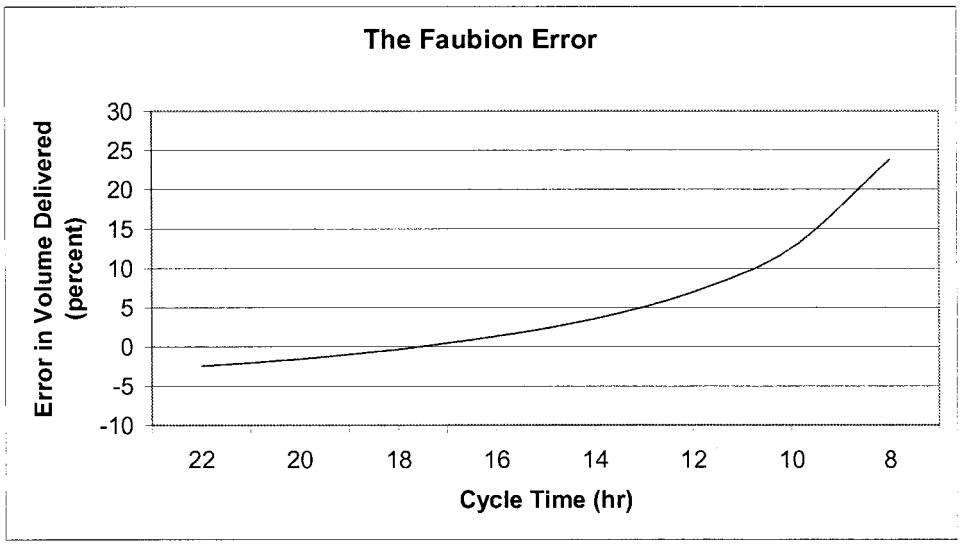

Figure 1. The previously published guideline for cycling TPN can deliver significantly different volumes of TPN than desired.

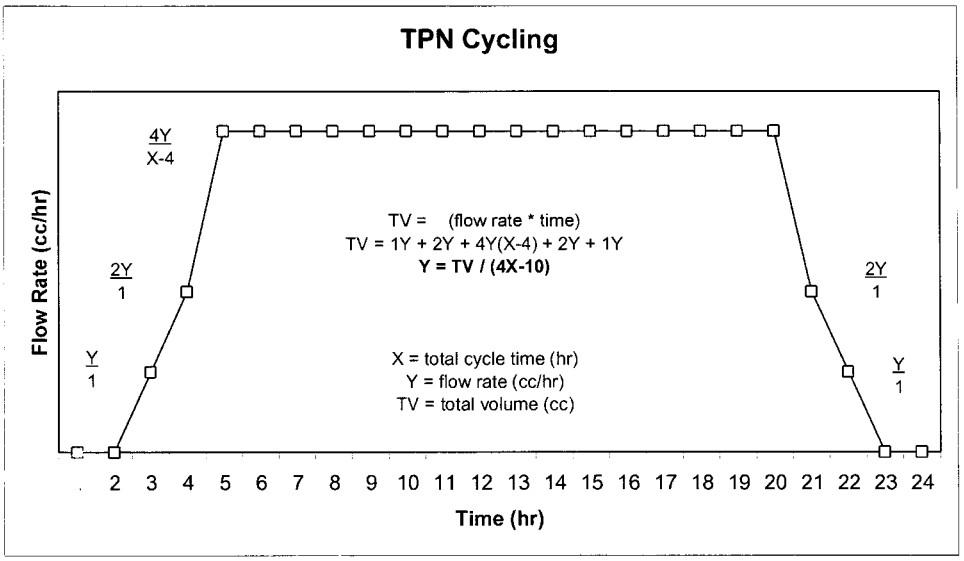

Figure 2. A mathematical overview of the method used to cycle TPN at Lucile Packard Children's Hospital using a 22-hour cycle for illustration purposes.

of 36.8 mL/h, 73.7 mL/h, and 147.4 mL/h during the times indicated above.

The Online Implementation

This formula has been widely used to calculate TPN cycles at our institution for >10 years. Although a spreadsheet was previously used to facilitate calculations, a web-based version was more recently developed for easier accessibility (Fig. 3). We welcome the reader to use this free tool located online at http://peds.stanford.edu/tpn.html. By entering the TPN volume and the number of

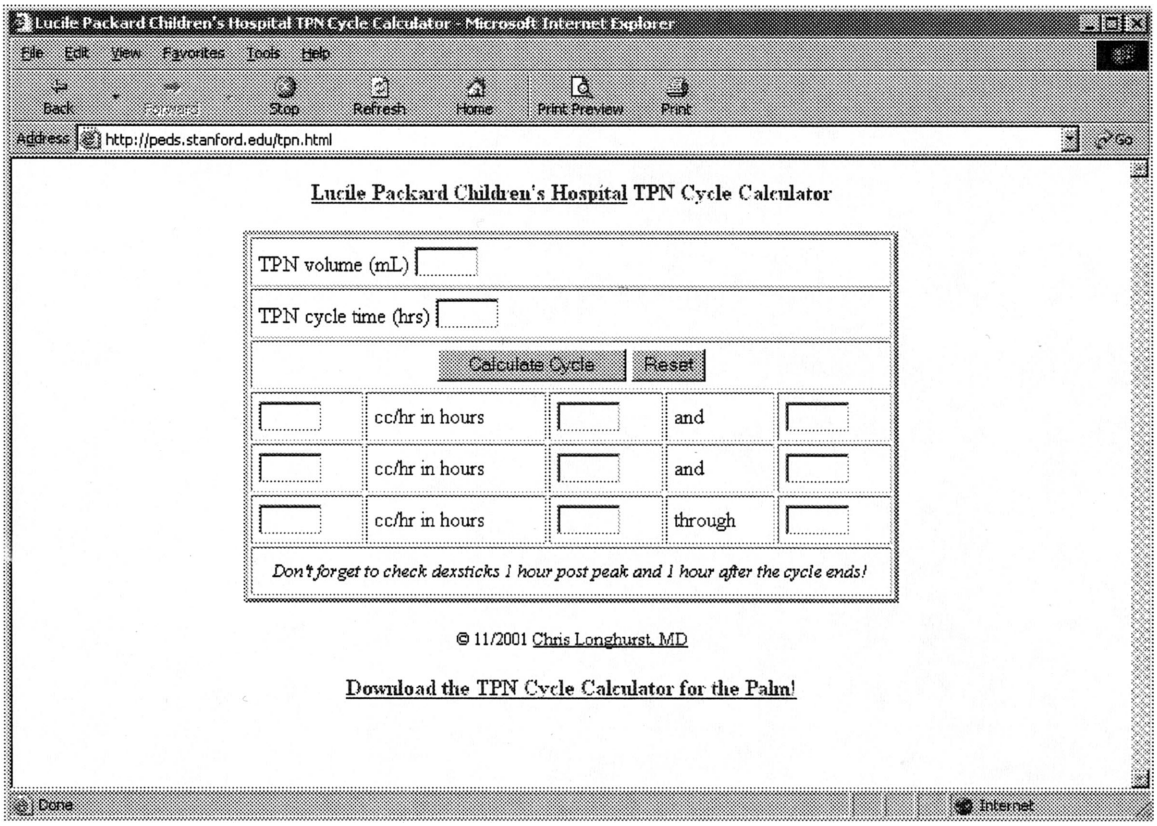

Figure 3. The TPN cycle calculator available online at http://peds.stanford.edu/tpn.html.

hours over which it should be cycled, users can instantly calculate flow rates that, when administered correctly, will always deliver the desired volume. A link with an example of a typical order for cycling TPN can also be found on the same website. Of note, the importance of using a similar online tool to prevent medical errors was recently established in a paper that also convincingly demonstrated that such a tool rapidly gained enthusiastic support from users.[13]

Discussion and Future Directions

In conclusion, we have developed a rapid and reliable method for calculating TPN cycle flow rates, given the total volume of TPN and total cycle time. It is important to note, however, that the division of increasing and decreasing the rate by 1-hour time blocks is arbitrary. Using the same mathematical concepts, the TPN cycle flow rates could easily be increased and decreased over any amount of time. We did not investigate the physiologic effects of such cycling. Additionally, our tool does not calculate glucose infusion rates, a particular concern in the neonatal intensive care unit. Further studies are necessary to determine the optimal time over which TPN rates can be increased and decreased and to better elucidate the physiologic benefits and drawbacks of such cycles. We encourage future researchers to use a mathematically accurate method for calculating cycle flow rates in order to maintain consistent and accurate delivery of desired TPN volumes.

Acknowledgments

We thank Dr Stuart Turner, DVM, MS, for developing a Palm® handheld-based version of the TPN cycling program, also available at http://peds.stanford.edu/tpn.html. We thank Dr Monte Klaudt for reviewing this manuscript. The work was supported in part by the Carl and Patricia Dierkes Endowed Fund for Nutrition and Home Care.

References

1. Kerner JA. Cyclic TPN for hospitalized pediatric patients. In: Kerner JA, ed. *Manual of Pediatric Parenteral Nutrition*. New York, NY: Wiley Medical; 1983:307–311.
2. Collier S, Crouch J, Hendricks K, Caballero B. Use of cyclic parenteral nutrition in infants less than 6 months of age. *Nutr Clin Pract*. 1994;9:65–68.
3. Meehan JJ, Georgeson KE. Prevention of liver failure in parenteral nutrition-dependent children with short bowel syndrome. *J Pediatr Surg*. 1997;32:473–475.
4. Hwang TL, Lue MC, Chen LL. Early use of cyclic TPN prevents further deterioration of liver functions for the TPN patients with impaired liver function. *Hepatogastroenterology*. 2000;47:1347–1350.
5. Maini B, Blackburn GL, Bistrian BR, et al. Cyclic hyperalimentation: an optimal technique for preservation of visceral protein. *J Surg Res*. 1976;20:515.
6. Matuchansky C, Morichau-Beauchant M, Druart F, et al. Cyclic (nocturnal) total parenteral nutrition in hospitalized adult patients with severe digestive diseases. *Gasteroenterology*. 1981; 81:433–437.
7. Wood RJ, Bengoa JM, Rosenberg IH. Urinary C-peptide measurements in patients receiving continous and cyclic TPN. *J Lab Clin Med*. 1985;105:259–264.
8. Wagman LD, Newsome HH, Miller KB, et al. The effect of acute discontinuation of TPN. *Ann Surg*. 1986;204:524–529.
9. Nirula R, Yamada K, Waxman K. The effect of abrupt cessation of TPN on serum glucose: a randomized trial. *Am Surg*. 2000;66: 866–869.
10. Faubion WC, Baker WB, Iott BA, et al. Cyclic TPN for hospitalized pediatric patients. *Nutr Support Serv*. 1981;1:24–25.
11. Davis AM. Initiation, monitoring, and complications of pediatric parenteral nutrition. In: Baker RD, Baker SS, Davis AM, eds. *Pediatric Parenteral Nutrition*. New York, NY: Chapman & Hall; 1997:220–222.
12. Collier SB, Richardson DS, Gura KM, et al. Parenteral nutrition. In: Hendricks KM, Duggan C, Walker WA, eds. *Manual of Pediatric Nutrition*. 3rd ed. Ontario, Canada: B. C. Decker; 2000:259–263.
13. Lehmann CU, Conner KG, Cox JM. Provider error prevention: online total parenteral nutrition calculator. Proceedings of the AMIA annual symposium. 2002;435–439.