Techniques and Procedures: Guidelines for Managing Electrolytes in Total Parenteral Nutrition Solutions

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Techniques and Procedures

Guidelines for Managing Electrolytes in Total Parenteral Nutrition Solutions

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ABSTRACT: To many practitioners, managing electrolytes in total parenteral nutrition (TPN) solutions has been considered an art rather than a science. Electrolytes are typically taught by gut feeling rather than by a structured approach. Consequently, most practitioners manage electrolytes differently, with varying degrees of success. Inconsistent prescribing often results in over- or undercorrection, with consequential adverse events and/or increased workload. These inconsistencies led my organization to develop dosing guidelines for the management of electrolytes in parenteral nutrition solutions. The guidelines are based on the literature and our clinical experience. They are designed specifically to teach a standardized process for making electrolyte adjustments. They were also designed to give a better idea of the amounts of electrolytes needed and the expected corresponding change in serum levels. Since implementing the guidelines, we have noticed an improvement in electrolyte management.

Managing electrolytes in parenteral nutrition (PN) solutions is often considered an art rather than a science. Electrolytes are typically taught by gut feeling rather than by a structured approach to managing fluids and electrolytes. Consequently, most practitioners manage electrolytes differently, with varying degrees of success. In my organization, we found this to be a common problem that was associated with new residents entering our training program. Residents either made minute changes with little or no impact in serum levels, or dramatic changes that resulted in overcorrection. This in turn led to another change in the fluid, and a maintenance amount was never established. These inconsistencies led us to develop dosing guidelines for the management of electrolytes in PN solutions.

The goals of the Electrolyte Dosing Algorithms were as follows: (1) create a standardized process for adjusting electrolytes, (2) decrease time to correct electrolyte abnormalities, (3) decrease number of electrolyte changes in PN orders, and (4) create an easy-to-use teaching tool that would better predict electrolyte requirements and corresponding serum levels.

The Nutrition Subcommittee developed the algorithms on the basis of literature and clinical experience, and conditional approval by the P & T Committee was granted in 1992. The algorithms were used throughout the hospital on all types of patients, including patients with renal dysfunction and multiorgan system failure. One hundred and forty-four patients were evaluated, representing 696 patient days of PN therapy. Three hundred and seventy-six (54%) patient days were managed exclusively by our standard electrolyte composition. The remaining 320 (46%) patient days required adjustment of electrolytes. The most common reasons for adjusting electrolytes were hypokalemia, hypomagnesemia, and hypophosphatemia in trauma and refeeding, and hyperkalemia and hyperphosphatemia in renal dysfunction. There were 44 (38%) instances where the electrolyte algorithms were used and 72 (62%) incidents where traditional empiric dosing was used. In all 44 situations using the algorithms, serum electrolyte levels returned to normal within 48 hours. There were no adjustments resulting in overcorrection. The average time to correction of electrolyte abnormalities was 1.07 ± 0.47 days. Of the 72 situations treated outside of the algorithms, 56 (77.8%) corrected in 1 to 6 days and 7 (9.7%) overcorrected. It took an average of 2.5 ± 1.4 days to correct the serum abnormalities (see Table 1). The algorithms were felt to be a significant improvement from previous therapy; therefore, the Nutrition Subcommittee recommended the adoption of the algorithms to the P & T Committee. The P & T Committee granted final approval in 1992, and the algorithms were published in the Nutritional Support Services Handbook. The algorithms are not

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Table 1
Comparison of protocol vs nonprotocol

	Protocol	Nonprotocol
Number of abnormal values	44	72
Corrected	44 (100%)	56 (77.8%)
Overcorrected	0 (0%)	7 (9.7%)
Days to correct	1.07 ± 0.47	2.5 ± 1.4

mandatory, but all recommendations from the Nutritional Support Services follow the guidelines.

The algorithm for acute replacement of phosphate started out as a resident project. Before the study, the standard phosphate dose for hypophosphatemia was either 15 mmol/L or 30 mmol/L. In most cases with serum levels <1.5 mg/dL, this was not enough to raise the serum phosphate level to an acceptable level. The goal was to give a supplemental dose of phosphate that would increase serum levels to at least 2 mg/dL without causing hyperphosphatemia (serum level >4.5 mg/dL). Initial concerns included metastatic calcifications and overcorrection of serum phosphate levels. Three adjustments were made in an attempt to alleviate these problems. The infusion rate was limited to 7.5 mmol/L/h to give the phosphate time to enter the cell and to avoid depression of serum calcium levels and metastatic calcifications; the dose was empirically decreased by 50% in patients with renal disease; and an adjusted body weight was used in obese patients. Initial guidelines recommended were as follows: 0.125 mmol/L/kg for serum level from 1.6 to 2 mg/dL; 0.25 mmol/L/kg for levels from 1 to 1.5 mg/dL; and 0.5 mmol/L/kg for serum levels <1 mg/dL. After a pilot study, these guidelines were found subtherapeutic. The guidelines were then readjusted to their current levels (see Appendix K). Of particular interest was the fact that doses did not have to be adjusted for patients with renal dysfunction. The protocol is for acute replacement, and renal failure is not an issue unless there is a maintenance infusion, which may allow phosphate to accumulate. Hundreds of patients have been treated using the phosphate protocol. The supplementation guidelines increase the serum phosphate to greater than 2 mg/dL in 85% to 90% of the patients treated. There was only 1 patient with resultant phosphate levels higher than 4.5 mg/dL. This patient had renal disease and was receiving maintenance phosphate. The level was taken 72 hours after the supplemental dose was given. The resultant level of 5.1 mg/dL was probably due to the maintenance fluid and not the supplemental phosphate.

Unfortunately, a controlled study comparing these algorithms with other therapy has not been done. However, since implementation of the algorithms, a reduction in the number of changes needed in PN orders and the number of electrolyte abnormalities commonly seen with PN therapy have been observed.

When using the protocols, there are several points to remember:

1. Acute electrolyte problems are best corrected with a supplemental infusion; do not correct them with a maintenance solution such as PN. Reserve maintenance solution adjustments for chronic electrolyte problems.
2. Be conservative, as you can always add more. If too much potassium is added to a 24-hour bag, nutritional intake may be compromised if the solution has to be discontinued. If the patient is developing renal failure, be more conservative about the amounts of potassium, phosphate, and magnesium you administer.
3. These are only guidelines. When the clinical situation dictates, you must break from the guidelines and treat the patient as an individual.
4. The guidelines for adjusting electrolytes were designed for PN therapy and may or may not be applicable for other maintenance solutions.
5. Appendices L–P reflect electrolyte dosing that is based on a per-kilogram amount rather than a per-liter amount. This may be more applicable for practitioners using 3:1 solutions.

All of the electrolyte guidelines are similar in the manner they work. If there is a replacement dose for acute and maintenance electrolytes, both guidelines are included.

1. Choose the electrolyte to be adjusted (ie, sodium; Appendix F).
2. Select the column with the corresponding serum electrolyte (serum sodium 133). If the patient has a dilutional hyponatremia, 35mEq/L sodium would be added; if not dilutional then 70mEq/L would be added.
3. Add the amount of sodium indicated.
4. The next day, recheck the level; determine if the new level is high, low, or normal; and follow the corresponding arrow. If the serum sodium is still low (132), the sodium would be increased to 100 mEq/L for nondilutional hyponatremia or to 50 mEq/L for dilutional hyponatremia.
5. Continue to follow the flow chart until the level is normal—this is the maintenance amount needed—or until 154 mEq/L is reached (normal saline) or until all sodium has been removed.

Over the past several years at my institution, we have noticed a decrease in electrolyte abnormalities seen in TPN patients. Changes in electrolytes are usually moderate, and we do not see the swings from high to low serum levels when patients are overcorrected. We feel these changes are secondary to the guidelines and a structured approach to electrolyte management. On occasion, we do have patients that cannot be managed by the guidelines, but in general they work well.

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Appendix A
Laboratory corrections

Calcium correction for low serum albumin:[1]
Add 0.8 mg/dL to Ca^{++} level for every 1 mg/dL albumin is below 3.5 mg/dL.

Change in serum potassium due to pH changes:[2]
Add 0.5 mEq/L to K^+ level for every 0.1 unit the arterial pH is below 7.4.
Subtract 0.5 mEq/L to K^+ level for every 0.1 unit the arterial pH is above 7.4.

Changes in serum sodium due to high serum glucose:[3]
Add 1 mEq/L for every 100 mg/dL the serum glucose is over 100 mg/dL.

Appendix B
Water deficit equation[4]

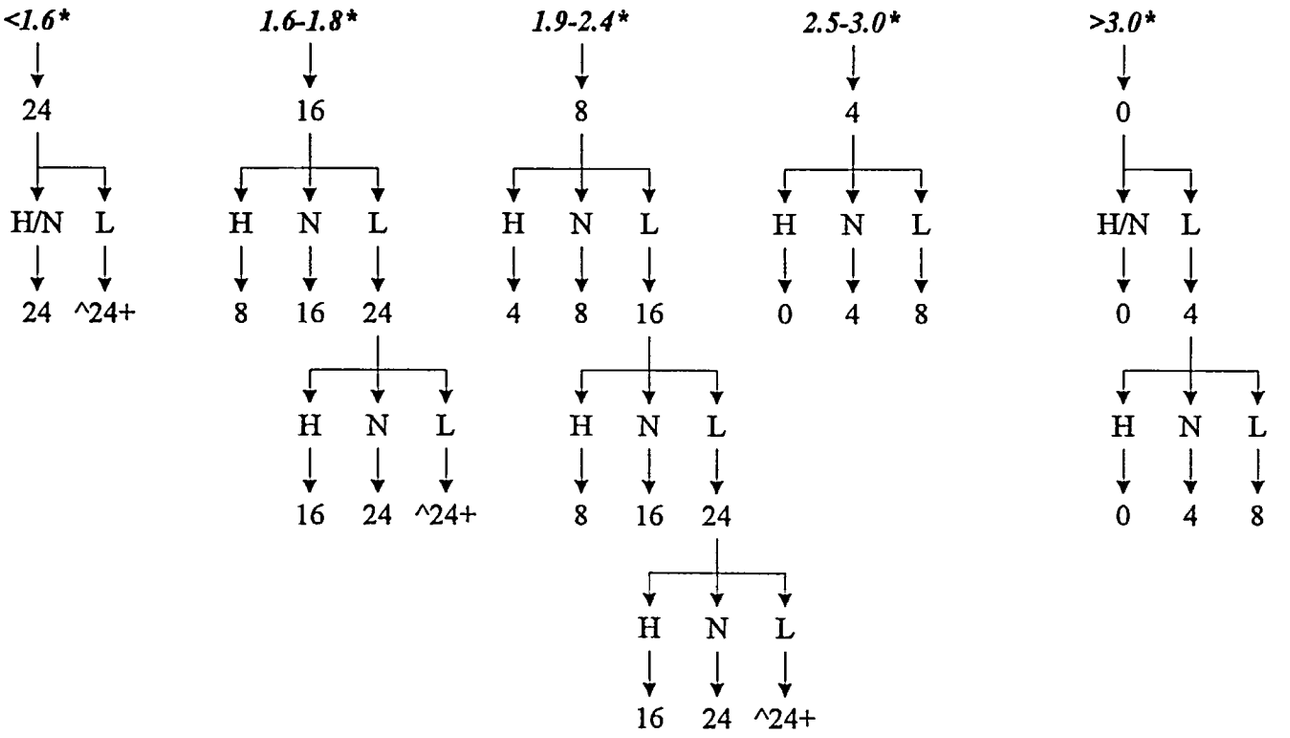
Water deficit (L) = ([measured serum Na^+ {mEq/L}]/140) − 1) × body weight (kg) × 0.6.
Initially, 50% of the free water deficit should be replaced over 12 hours with D_5W or 0.225% NaCl. Serum sodium should not be corrected faster than 2 mEq/L/h, or 12 mEq/L over 24 hours. Normal maintenance fluids should also be given throughout the replacement period.

Appendix C
Sodium deficit equation[2,5]

Na^+ deficit (mEq) = [140 − measured serum Na^+ (mEq/l)] × body weight (kg) × 0.6.
Initially, approximately 50% of the sodium deficit should be administered over 12 hours. Serum sodium should not be corrected faster than 2 mEq/L/hr or 12 mEq/L over 24 hours. In chronic hyponatremia, serum sodium should not be corrected faster than 0.5 mEq/L/hr.

Appendix D
Magnesium maintenance[1,4,6–8]

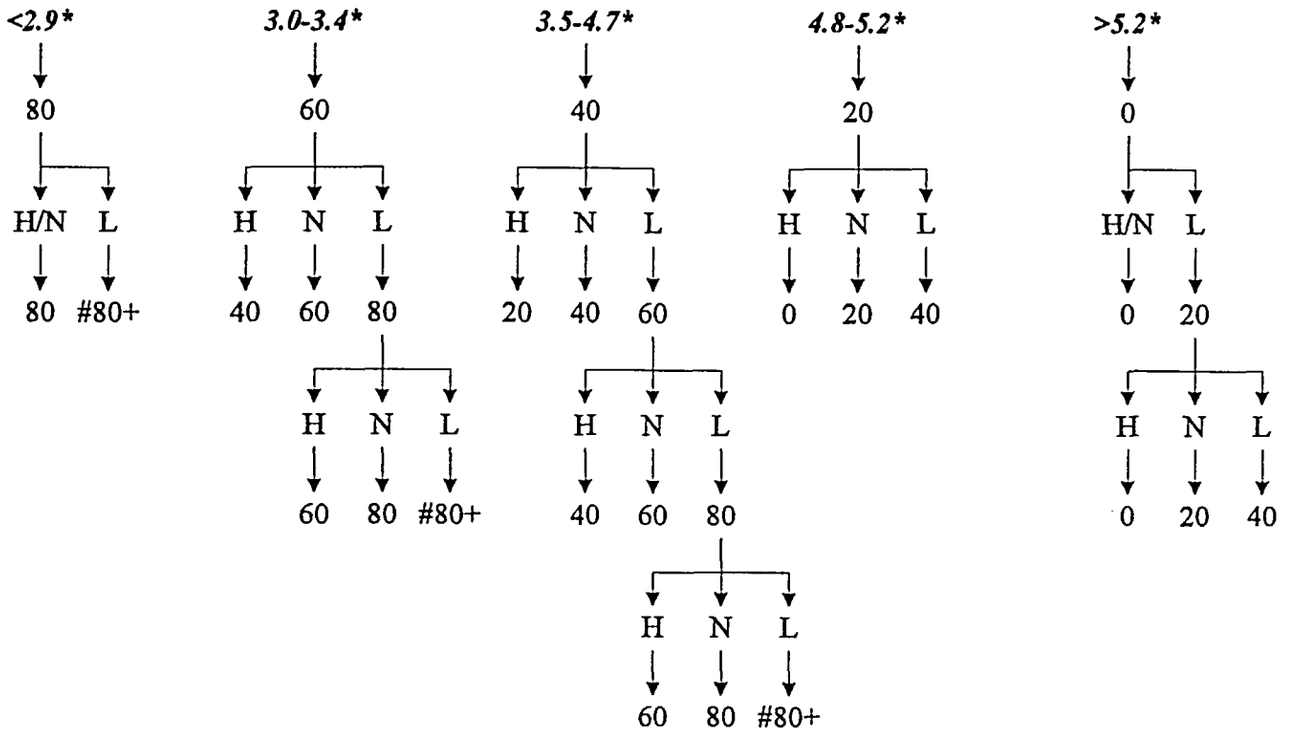
Cautions: Renal failure, malnutrition, trauma



Directions: Begin in the column with the corresponding serum level and follow the chart accordingly. On the second day continue in the same column and make changes according to serum levels, high, low or normal. Once the patient has normal levels continue that supplementation.
H = >2.4, N = 1.9-2.4, L = < 1.9mg/dL
*Values are in mg/dL
^24+ = 24mEq magnesium per liter plus magnesium acute replacement (Appendix I.)
If SCr > 1.5mg/dL, move one column to the right.
If SCl < 1.5mg/dL, and malnutrition or trauma, move one column to the left.
Compatibility and stability must be checked prior to mixing any parenteral nutrition solution.

Appendix E
Potassium maintenance[1–3,9–10]

Cautions: Acid-base disorders, renal failure, trauma



Directions: Begin in the column with the corresponding serum level and follow the chart accordingly. On the second day continue in the same column and make changes according to serum levels, high, low or normal. Once the patient has normal levels continue that supplementation.

H = > 4.7, N = 3.5 – 4.7, L = < 3.5 mEq/L

*Values are in mEq/L

#80+ = 80mEq potassium per liter in PN or 60-80mEq potassium per liter in PN plus potassium acute replacement (Appendix J).

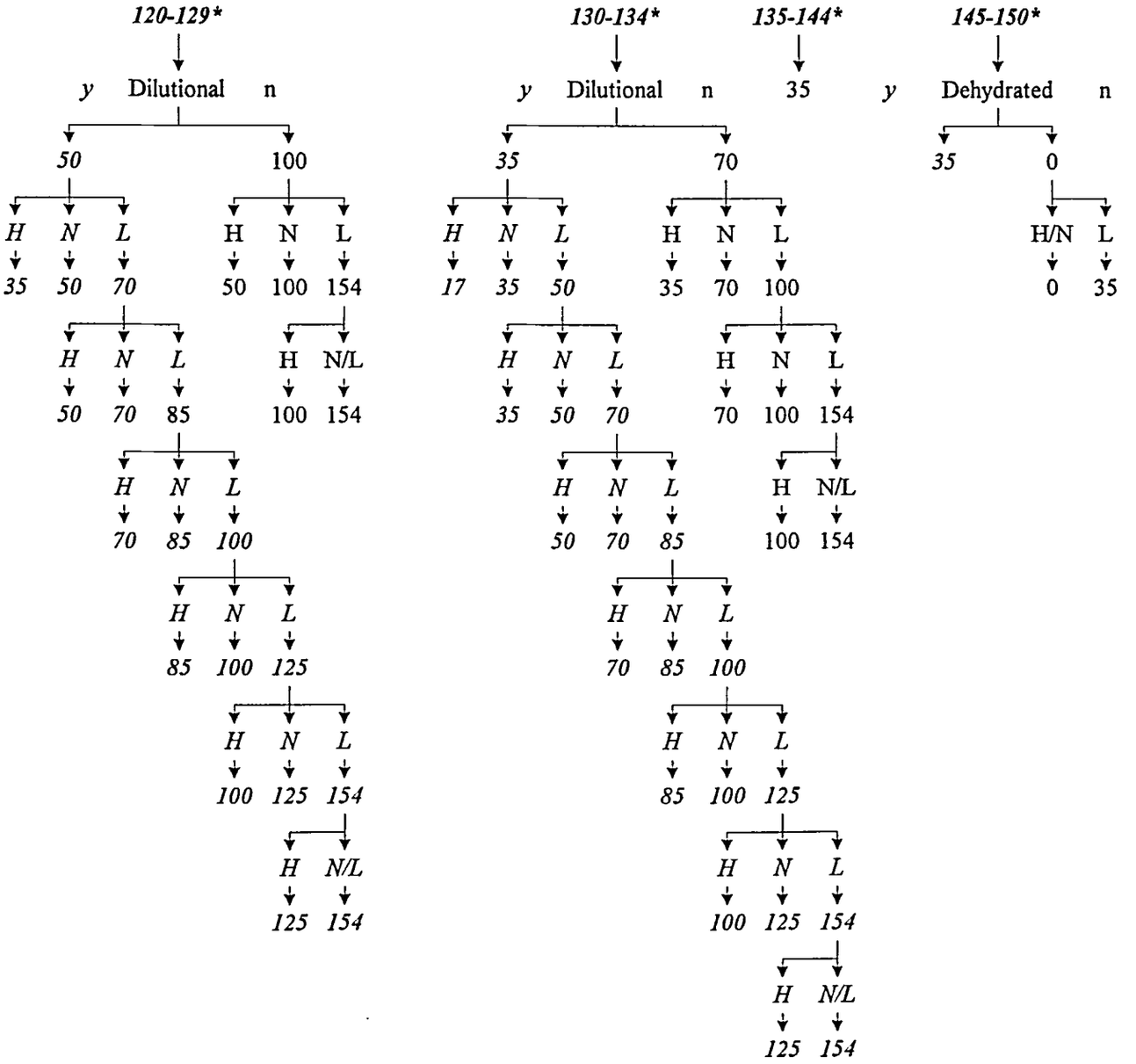
If SCr > 1.5mg/dL, move one column to the right.

If SCr < 1.5mg/dL, and malnutrition or trauma, move one column to the left.

Compatibility and stability must be checked prior to mixing any parenteral nutrition solution.

Appendix F
Sodium maintenance[1-5,11-15]

Cautions: Fistulas, sodium containing medications, NG output. Closed head injury does not apply. Dehydration and fluid overload must be treated primarily by volume expansion or fluid restriction respectively.



Directions: Begin in the column with the corresponding serum level, determine if patient is fluid restricted or not and follow chart accordingly. On second day continue in same column and make changes according to serum levels, high, normal or low. Once patient has normal levels continue that supplementation

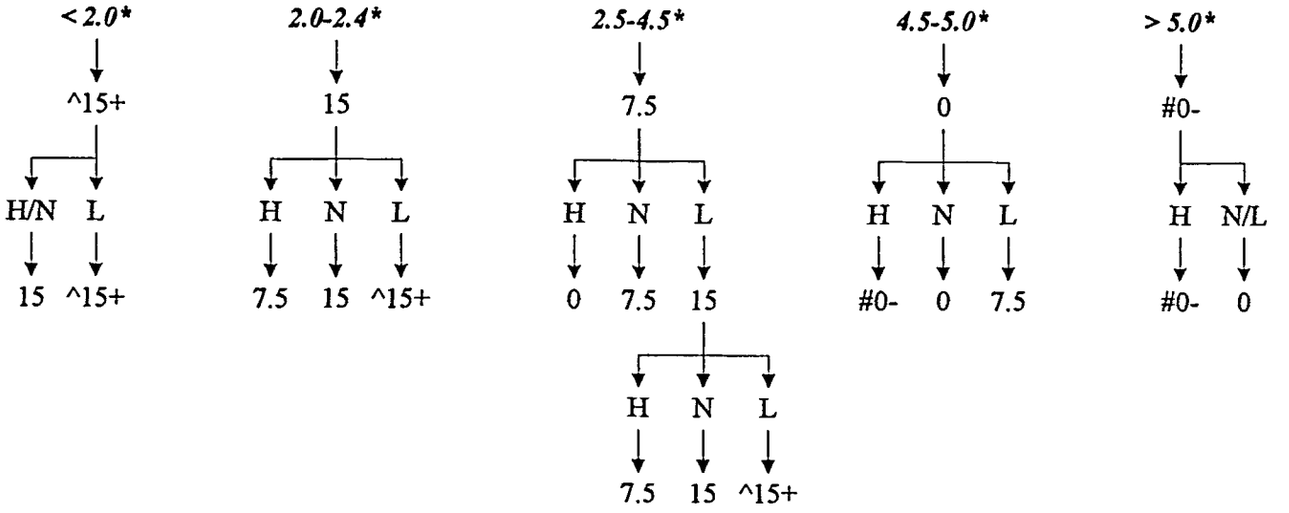
H = > 144, N = 135 – 144, L = < 135 mM/L.

Serum sodium value are in mM/L, all other values are amounts of sodium to be added to TPN solutions in mEq/L.

Compatibility and stability must be checked prior to mixing any parenteral nutrition solution.

Appendix G
Phosphate maintenance[1–3,16]

Cautions: Alcoholism, malnutrition, renal failure, trauma



Directions: Begin in the column with the corresponding serum level and follow the chart accordingly. On the second day continue in the same column and make changes according to serum levels, high, normal, or low. Once the patient has normal levels continue that supplementation.

H = > 4.5, N = 2.5 – 4.5, L = < 2.5 mg/dL

*Serum phosphorus values are in mg/dL, all other values are mM/L.

If SCr > 2.0mg/dL, move one column to the right.

If SCr > 2.0mg/dL, and trauma, malnutrition, or acidosis (pH < 7.2) move one column to left

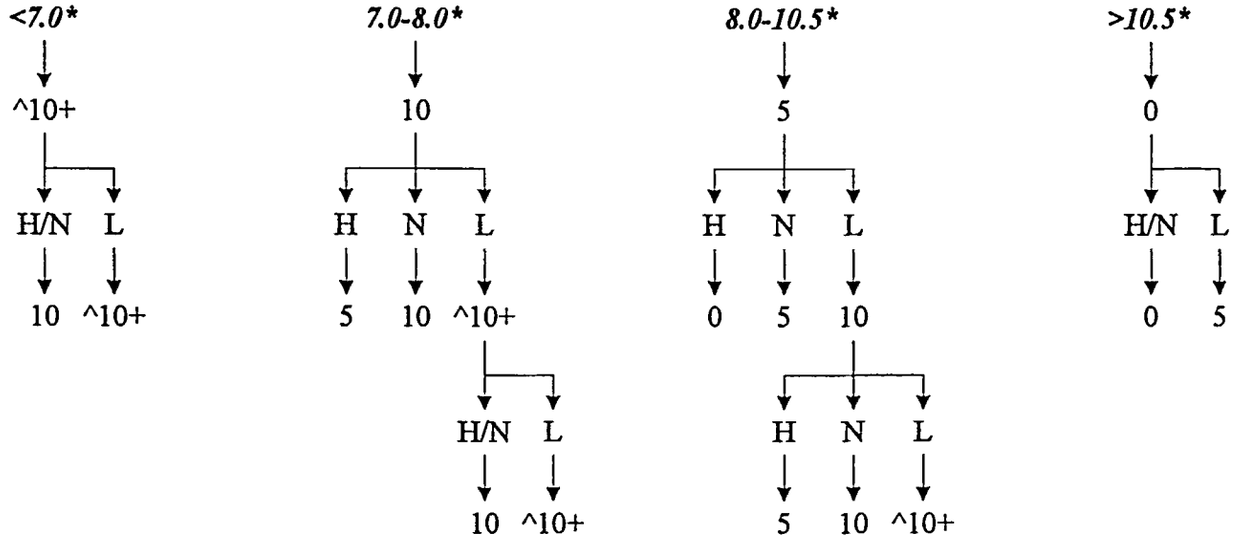
^15+ = 15mM/L plus acute replacement (Appendix K).

#0- = no phosphate in TPN, lipids may need to be held if phosphorus levels continue to increase.

Compatibility and stability must be checked prior to mixing any parenteral nutrition solution.

Appendix H
Calcium maintenance[1–3,17]

Cautions: Bone cancer, renal failure, parathyroid disease, hypoalbuminemia



Directions: Begin in the column with the corresponding serum calcium level and follow the chart accordingly.

H = >10.5, N = 8.0 – 10.5, L = < 8.0g/dL

Serum calcium levels must be corrected for hypoalbuminemia when appropriate before using the flow chart. (Add 0.8mg/dL to serum calcium levels for every 1g/dL albumin <3.5g/dL.)

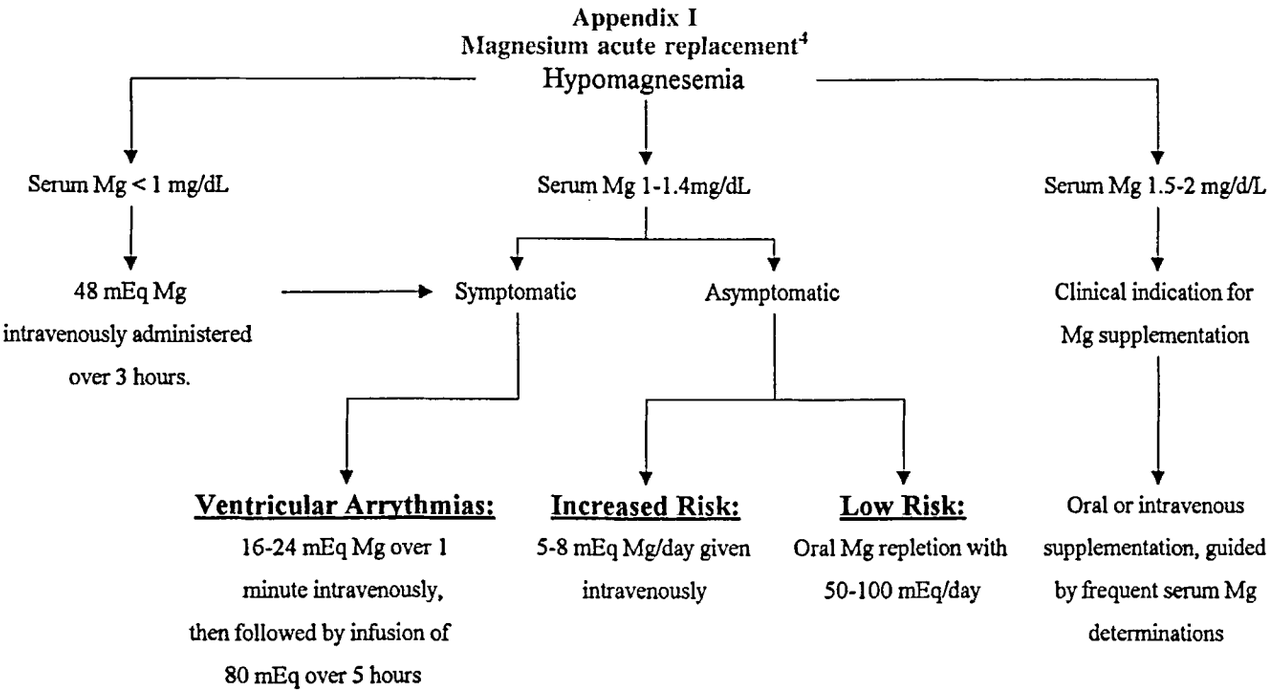
Ionized calcium levels should be checked prior to adding more than 10mEq/L calcium or if serum calcium levels are > 10.5mg/dL corrected.

*Serum calcium values are in mg/dL, all other values are in mEq/L.

^10+ = 10mEq/L plus acute replacement.

Compatibility and stability must be checked prior to mixing any parenteral nutrition solution.

Appendix I
Magnesium acute replacement[4]

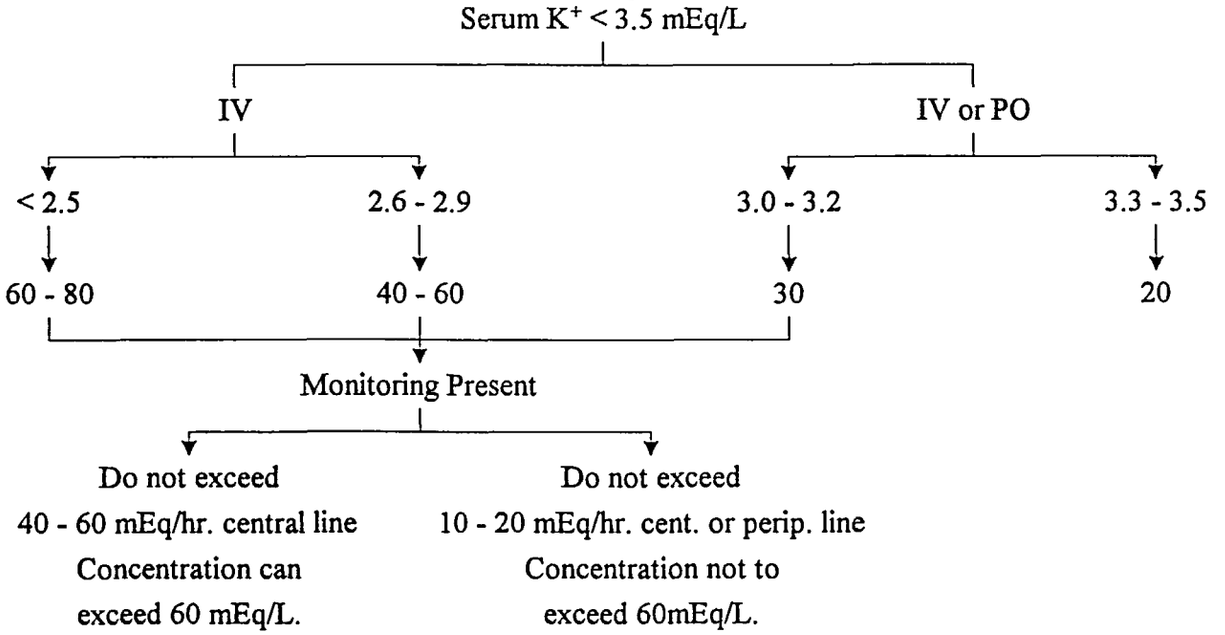


Treatments are listed in the suggested sequence of consideration. Serum magnesium concentrations should be measured every 8 hours during the initial treatment phase and every 12 – 24 hours following stabilization (> 1.4 mg/dL), which should occur within 24 hours.

Magnesium should be given no faster than 4mEq/hr, although, there is literature to suggest that magnesium should be given no faster than 0.05mEq/kg/hr. If weight is truly a consideration, Appendix Q shows the minimum time 1 gram of magnesium sulfate (8mEq) should be administered[18,19].

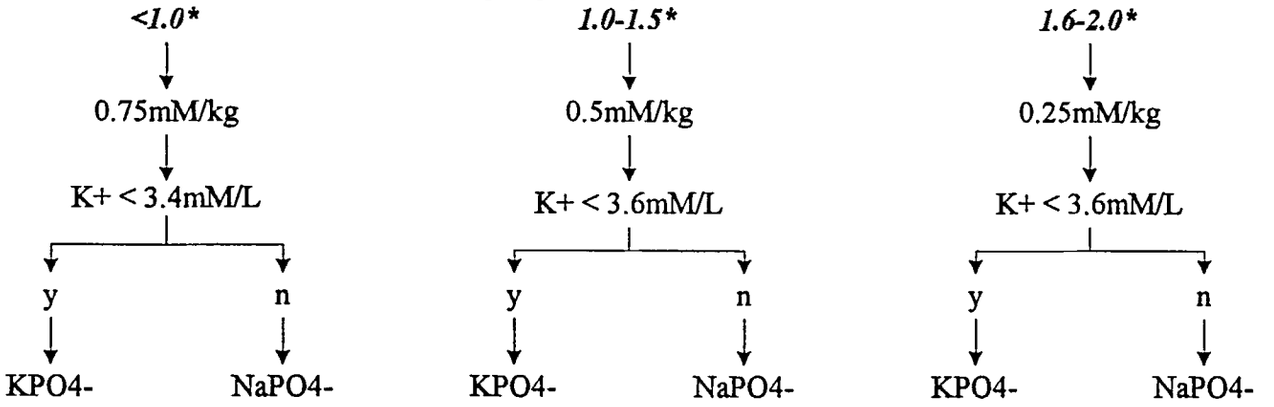
Algorithms for acute replacement should be reserved for patients with regular monitoring and may not be appropriate for patients in the home care setting.

Appendix J
Potassium acute replacement[4]



Repeat level every 6 hours during acute replacement and after every 60 - 80 mEq infusion.
Extend monitoring interval to every 12 - 24 hours after $K^+ > 3.5$ mEq/L.
Algorithms for acute replacement should be reserved for patients with regular monitoring and may not be appropriate for patients in the home care setting.

Appendix K
Acute phosphate replacement[1–4,16,20–23]



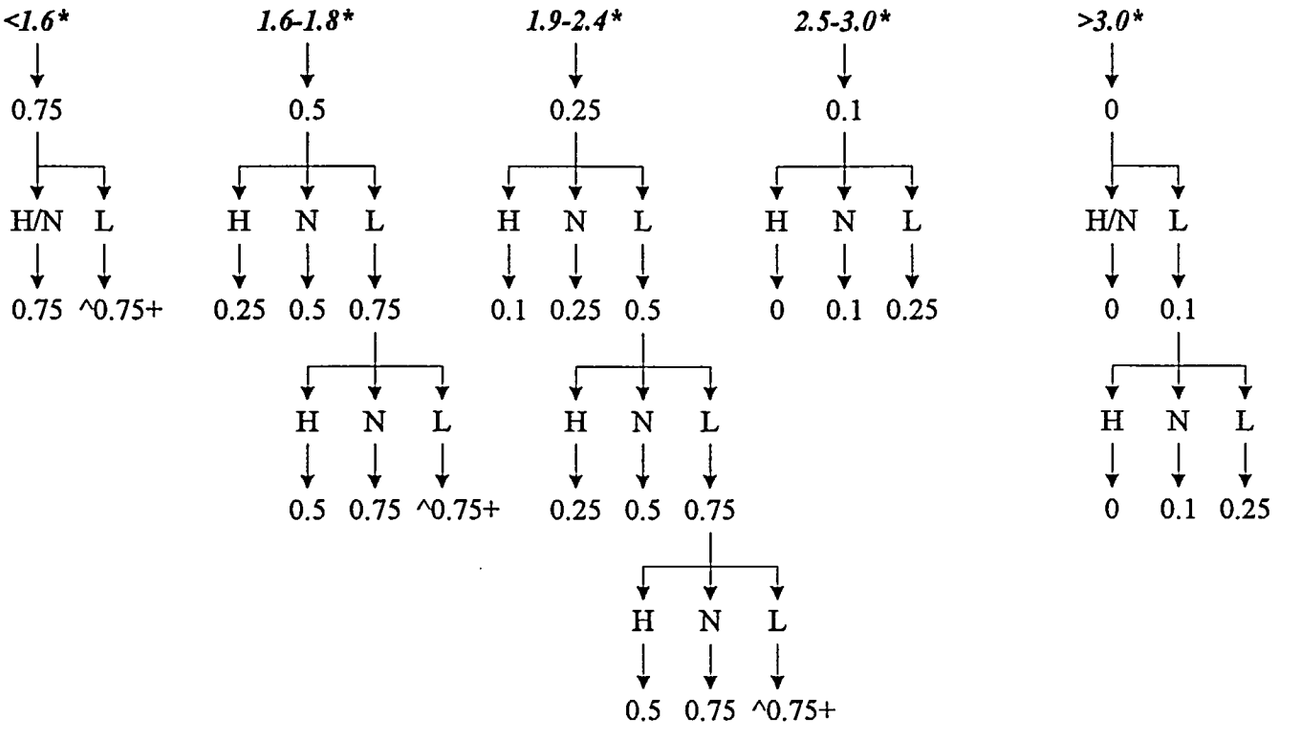
Directions: Begin in the column with the corresponding serum phosphorus level. Based on the serum potassium level determine whether sodium or potassium phosphate is most appropriate.

*Serum phosphorus values are in mg/dL, all other values are amounts of phosphate to be given as an infusion no faster than 7.5mM/hr. If patient > 115% IBW, use an average of IBW and actual body weight.

Algorithms for acute replacement should be reserved for patients with regular monitoring and may not be appropriate for patients in the home care setting.

Appendix L
Maintenance magnesium/Kg[1,4,6–8]

Cautions: Renal failure, malnutrition, trauma



Directions: Begin in the column with the corresponding serum level and follow the chart accordingly. On the second day continue in the same column and make changes according to serum levels, high, low or normal. Once the patient has normal levels continue that supplementation.

H = >2.4, N = 1.9-2.4, L = < 1.9mg/dL

*Values are in mg/dL

^0.75+ = 0.75mEq/Kg magnesium plus acute replacement (Appendix I).

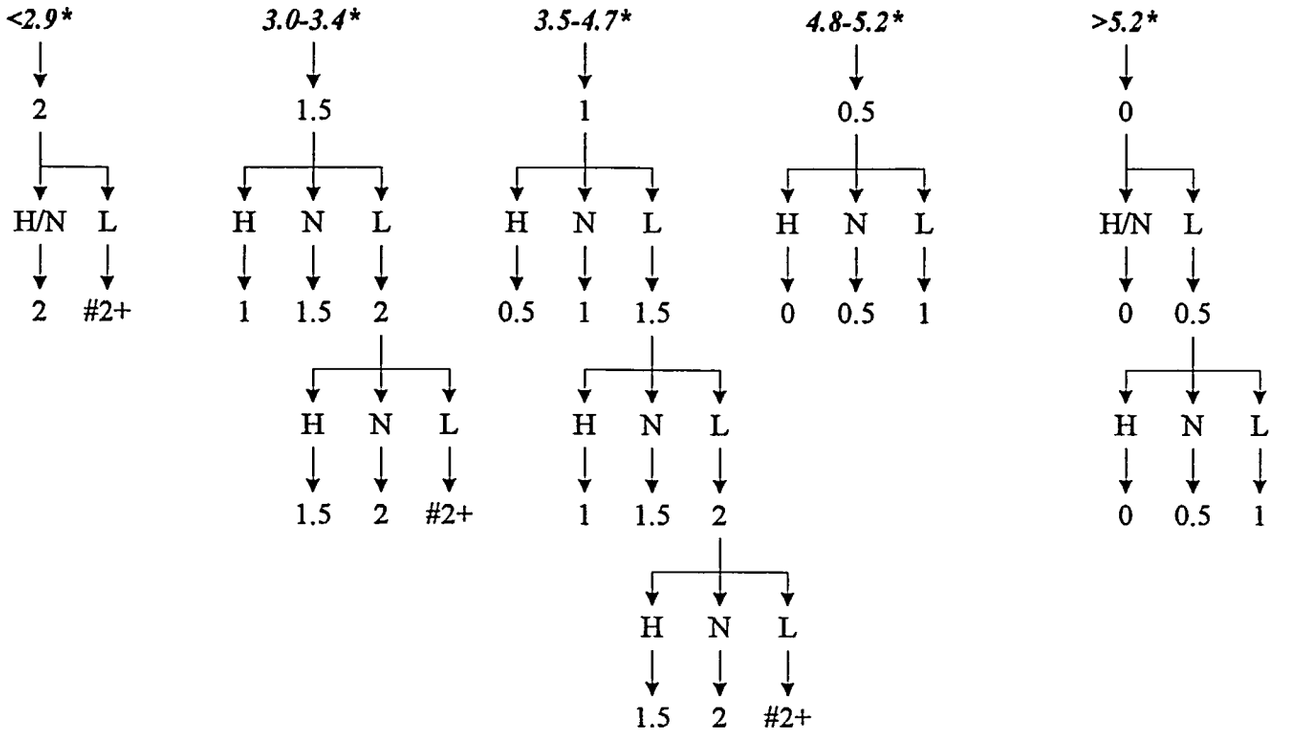
If SCr > 1.5mg/dL, move one column to the right.

If SCl < 1.5mg/dL, and malnutrition or trauma, move one column to the left.

Compatibility and stability must be checked prior to mixing any parenteral nutrition solution.

Appendix M
Maintenance potassium/Kg[1–3,9–10]

Cautions: Acid-base disorders, renal failure, trauma



Directions: Begin in the column with the corresponding serum level and follow the chart accordingly. On the second day continue in the same column and make changes according to serum levels, high, low or normal. Once the patient has normal levels continue that supplementation.

H = > 4.7, N = 3.5 – 4.7, L = < 3.5 mEq/L

*Values are in mEq/L

#2+ = 2mEq/Kg in PN or 1.5 – 2 mEq/Kg plus potassium acute replacement (Appendix J).

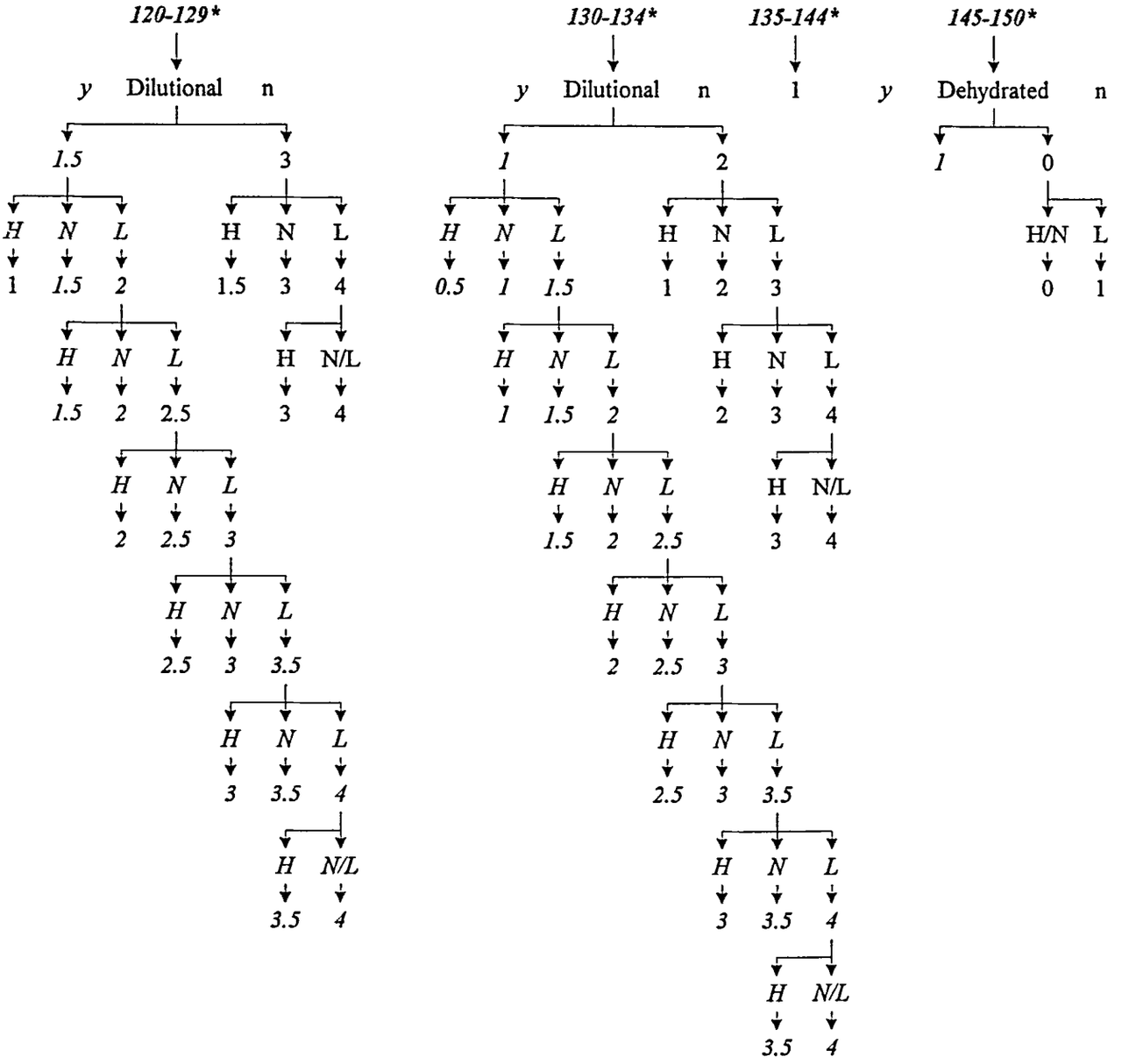
If SCr > 1.5mg/dL, move one column to the right.

If SCr < 1.5mg/dL, and malnutrition or trauma, move one column to the left.

Compatibility and stability must be checked prior to mixing any parenteral nutrition solution.

Appendix N
Maintenance sodium/Kg[1–5,11–15]

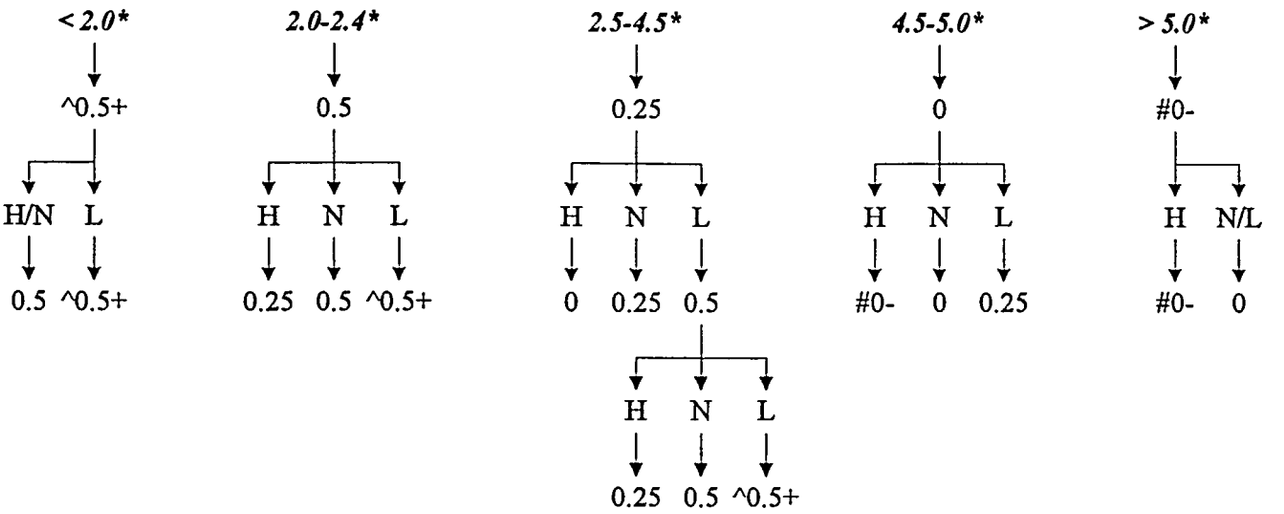
Cautions: Fistulas, sodium containing medications, NG output. Closed head injury does not apply. Dehydration and fluid overload must be treated primarily by volume expansion or fluid restriction respectively.



Directions: Begin in the column with the corresponding serum level, determine if patient is fluid restricted or not and follow chart accordingly. On second day continue in same column and make changes according to serum levels, high, normal or low. Once patient has normal levels continue that supplementation.
H = > 144, N = 135 – 144, L = < 135 mM/L.
*Serum sodium value are in mM/L, all other values are amounts of sodium to be added to TPN solutions in mEq/Kg.
Compatibility and stability must be checked prior to mixing any parenteral nutrition solution.

Appendix O
Maintenance phosphate/Kg[1–3,16]

Cautions: Alcoholism, malnutrition, renal failure, trauma



Directions: Begin in the column with the corresponding serum level and follow the chart accordingly. On the second day continue in the same column and make changes according to serum levels, high, normal, or low. Once the patient has normal levels continue that supplementation.

H = > 4.5, N = 2.5 – 4.5, L = < 2.5 mg/dL

*Serum phosphorus values are in mg/dL, all other values are mM/Kg.

If SCr > 2.0mg/dL, move one column to the right.

If SCr > 2.0mg/dL, and trauma, malnutrition, or acidosis (pH < 7.2) move one column to left

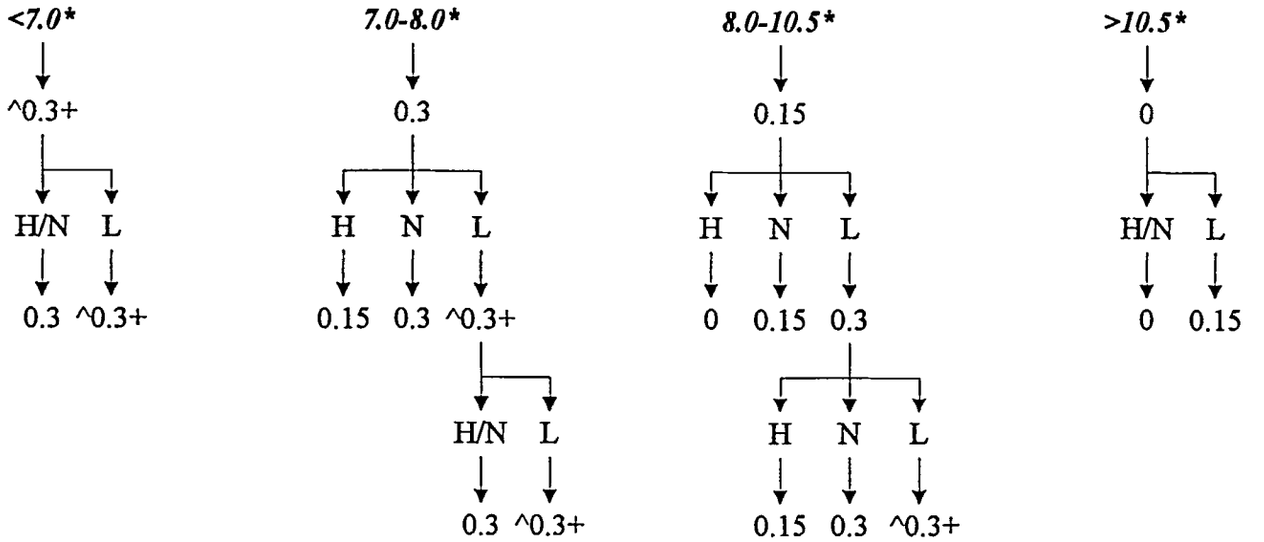
^0.5+ = 0.5mM/Kg plus acute replacement (Appendix K).

#0- = no phosphate in TPN, lipids may need to be held if phosphorus levels continue to increase.

Compatibility and stability must be checked prior to mixing any parenteral nutrition solution.

Appendix P
Maintenance calcium/Kg[1–3,17]

Cautions: Bone cancer, renal failure, parathyroid disease, hypoalbuminemia



Directions: Begin in the column with the corresponding serum calcium level and follow the chart accordingly.

H = >10.5, N = 8.0 – 10.5, L = < 8.0g/dL

Serum calcium levels must be corrected for hypoalbuminemia when appropriate before using the flow chart. (Add 0.8mg/dL to serum calcium levels for every 1g/dL albumin <3.5g/dL.)

Ionized calcium levels should be checked prior to adding more than 0.3mEq/Kg calcium or if serum calcium levels are > 10.5mg/dL corrected.

*Serum calcium values are in mg/dL, all other values are in mEq/Kg.

^0.3+ = 0.3mEq/Kg plus acute replacement.

Compatibility and stability must be checked prior to mixing any parenteral nutrition solution.

Appendix Q
Magnesium infusion times adjusted for weight

Weight in kilograms	Infuse 1 gram (8 mEq) $MgSO_4$ over
40	4 hours
50	3.2 hours
60	2.6 hours
70	2.3 hours
80	2 hours
90	1.8 hours
100	1.6 hours
120	1.3 hours