Parenteral nutrition (PN) admixtures contain a broad range of components in varying amounts and combinations. There are several application systems available to meet various patient needs, including:

- **Single-bottle systems**
- **All-in-one systems**

**Single-Bottle Systems**

With single-bottle systems, amino acids, glucose, lipids and electrolytes are administered in parallel from separate bottles by combining multiple connectors that feed into a common IV catheter. Vitamins and trace elements are usually added to PN from concentrated preparations.1,2
The single-bottle system is associated with various disadvantages rendering its use inconvenient in clinical practice:

- Need for a connector and multiple administration sets
- Requiring frequent bottle changes
- Necessity to set up different, irregular flow rates and make many additions
- Increased probability of administration errors
- Time consuming

However, if handled correctly, single-bottle systems offer wide flexibility when it comes to dosage and enabling highly specific PN therapy, adjusting to various patient needs.\(^1,2\)

**All-In-One Systems**

All-in-One (AiO) systems combine all components of PN, macronutrients, water, electrolytes, vitamins and trace elements, in one container to be administered via a single infusion line.\(^2\)

The clinical advantages of AiO admixtures include:

- Simultaneous supply of all nutrients\(^2,4,5\)
  - Improved utilization and nitrogen balance\(^2,4,5\)
  - Less metabolic complications\(^1,2\)
- Fewer manipulations
  - Reduced risk of infections\(^2,6\)

AiO systems come in three forms:

- Compounding PN
Compounding PN: Ready-To-Use Admixtures

As in the AiO system, compounding enables the provision of ready-to-use admixtures that can be adjusted to the energy, volume and substrate needs of the majority of patients. Customized admixtures are often mandatory in patients with rapidly changing metabolic requirements (e.g. critical care patients, and patients with metabolic disorders or fluid restriction). The simultaneous administration of all substrates reduces the risk for metabolic complications.\textsuperscript{1}

Compounded bags are aseptically manufactured from various sterile components, usually in hospital pharmacies, and are designed for immediate intravenous administration with no mixing or admixing of further ingredients required. Due to physicochemical instability, compounded bags require short-term production according to strict aseptic techniques by pharmaceutical experts. Proper storage of compounded bags should be in a temperature range of two to eight °C.\textsuperscript{1}

The use of compounded bags does have several limitations, including:

- High expenditure of time, material, and facility
- High staff costs
- Higher risk of prescription errors\textsuperscript{7}
- More blood stream infections\textsuperscript{8}
- Higher cost versus multi-chamber bags\textsuperscript{9}

Under specific clinical conditions, nutritional therapy needs to be adapted accordingly. Specific clinical conditions include\textsuperscript{10}:

- Patients with heart failure (need for low volume/more concentrated PN)
- Patients with chronic renal failure and oliguria (require a Na/K-restricted, low volume PN-therapy)
- Patients with hepatic failure (benefits of branched-chain amino acid BCAA-enriched PN)
- Patients with gut failure or high output fistulas (increased requirements for electrolytes, vitamins and trace elements)
- By using stress factors, the requirements can be further defined.

Automated Compounding

In many large hospital centers, compounding of PN is performed using automated compounding devices. Compared to manual manufacturing, using such devices can lower the risk of human errors, improve the accuracy of compounding and reduce personnel workload.\textsuperscript{11,12}

Multi-Chamber Bags

Two-Chamber Bags

Two-Chamber Bags are standard AiO bags with two chambers containing glucose and amino acids to be mixed together immediately prior to intravenous infusion by breaking the separation seals between the bag chambers. The lipid emulsion is admixed with a transfer set
shortly prior to administration. Vitamins, trace elements and additional electrolytes are either added to the lipid emulsion or infused by a separate intravenous line. When not mixed together, these bags have a shelf life of more than 12 months.  

Three-Chamber Bags

Three-Chamber Bags (3CBs) systems are standard AiO bags that allow delivery of macronutrients, with or without electrolytes, provided in three separate compartments that are divided by seals which can easily be opened prior to administration by rolling up the bag. Micronutrients (vitamins and trace elements) can be added to the reconstituted mixture as needed.
Compared to other application systems, 3CBs possess a number of key advantages:

- Sustained convenience in parenteral nutrition
- Save costs and time\(^{13}\)
- Flexible and adaptable therapy covering the needs of the majority of patients\(^{14}\)
- Increase safety of mixtures regarding stability and sterility as well as safety and efficacy of therapy\(^{2,14-16}\)

**Modes of Delivery**\(^{3}\)

PN may be delivered using a pump for intravenous feeding or by gravity. Criteria for the choice of the appropriate mode of delivery include:

- Infusion rate
- Duration of infusion
- Required precision
- Therapeutic aims

Infusion by gravity relies on hydrostatic pressure without the assistance of an infusion pump. The infusion rate is regulated by a passive flow controller and calculated basing on the drip rate. The flow controller can be a roller clamp interacting with the tube directly or a specific flow rate controller. The latter achieves a higher accuracy and stability of flow rate. Gravity infusion is recommended if demands for infusion rate and precision are comparatively low.

Pump-assisted infusion is performed by means of a volumetric pump working in combination with infusion systems or by means of syringe devices controlling flow with a motor-driven piston. This approach is appropriate for low-volume infusions. Pump-assisted infusion ensures high precision with constant infusion rates and enables programmable rate cycling.

**References**


