

Instructions for Use of Parallel Infusions

For patient's safety

When devices are combined in such a way that the safety of an infusion pump could be impaired by the ready-to-use equipment it is ported together with, these combinations of devices may be used only if they are described in this instructions manual or the technical safe feasibility of the combination has been tested and certified by an EC notified body for infusion pumps.

Instructions for Use of Parallel Infusions

1. Situation

With all the benefits that infusion therapy has to offer, it also poses risks to the patients by potentially leading to:

- **Adverse dose fluctuations**
- **Ruptures from high pressure build-up**
- **Air in the line**
- **Occlusions that are identified too late or not at all.**

By making the suitable product selection, being knowledgeable about the systems and ensuring the appropriate monitoring, the user can implement safe infusion therapy while preventing potential hazards.

The successful implementation of infusion therapy with single infusions tends to be problem-free, while parallel infusions¹⁾ increase complexity and thereby difficulty.

Parallel infusion is defined as the porting together of 2 or more infusions leading into one common access site on the patient.

With parallel infusions, the gravity infusions and apparatus involved are connected together through the infusion lines and can mutually affect each other. These interactions can result in hazards for the patient that would not otherwise be created when single infusions are used.

Every possible combination of different infusion systems can be implemented:

- **Gravity + gravity** - with and without infusion controller or monitoring equipment
- **Pumps + pumps** – large volume and syringe pumps
- **Pumps + gravity**

On intensive care units, single infusions tend to be the exception rather than the rule. Frequently, equipment of varying type, age and development status from different manufacturers are used on one patient. Every application form – gravity or pump – has its own specific advantages and disadvantages and/or areas of application, which is why it does not make sense to rule out specific combinations.

It is the users' responsibility to comply with the directions for use; thereby they can and must make a major contribution to enhancing patient safety.

Additionally, a number of technical assistive devices and monitoring equipment are available that make it safer to implement and carry out parallel infusions. Outlay and benefits should be weighed very carefully in each context. Not all potential equipment and setups enhance safety to the desired extent. For the user, they can make the infusion regimen more complicated because the greater the number of devices that are used, the greater can be the number of undesirable alarms. But, ultimately, an abundance of technical support can never replace proper supervision and monitoring by medical personnel.

Only qualified users will be able to master such complex situations.

The instructions below should illustrate for the user the type and nature of the specific hazards that can occur with the different combinations of infusion systems, while providing both application guidelines and listing the types of monitoring equipment that make parallel infusions safe to implement and manage.

2. Potential hazards during parallel infusions

Both single and parallel infusions can put patients at risks, if and when

- **Air in-line**
- **Underdosage**
- **Overdosage**
- **Ruptures**

are identified too late or not at all.

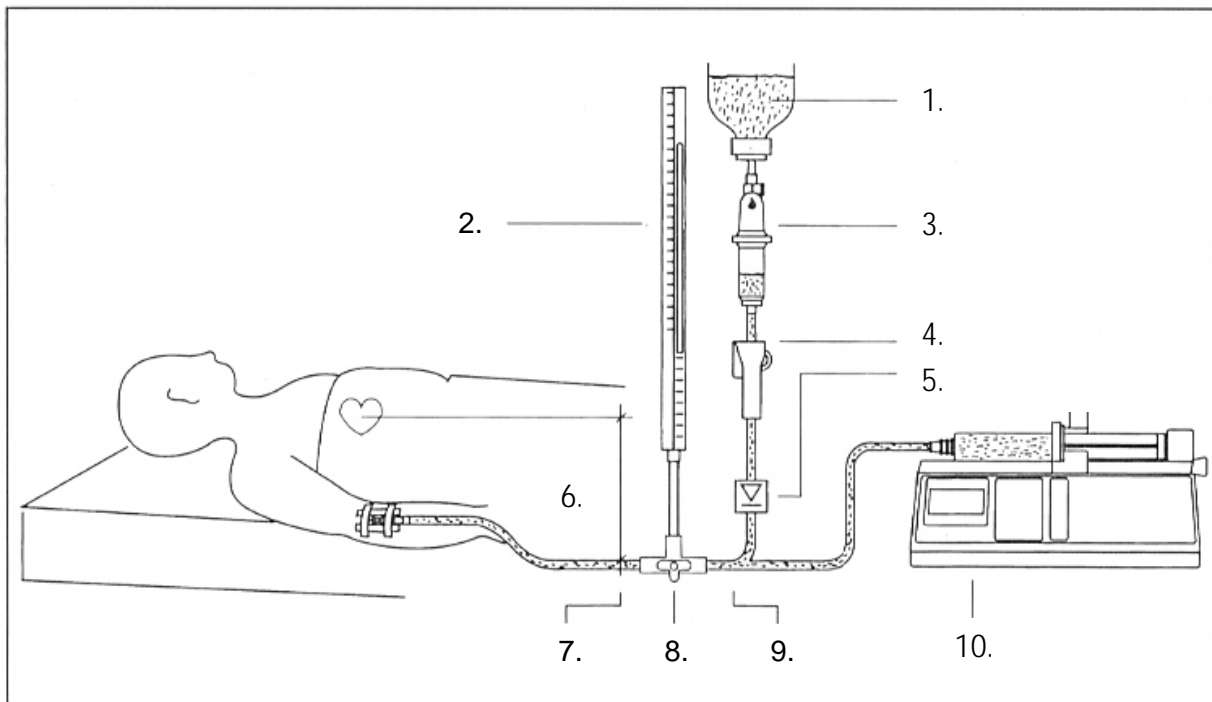
Depending on the pressure situation and rupture site, ruptures can lead to:

- **Underdosage due to escaping infusion solution**
- **Leakage of blood or**
- **Penetration of air.**

The extent of the damaging effect mainly depends on the patient's condition (age, weight, nature and severity of the disease etc.) and on the action of the drug administered.

For example, over- or underdosage of parenteral nutrition is better tolerated than when highly potent drugs such as catecholamines are involved.

The figure on the next page illustrates an example of a parallel infusion. For better overview in this example only a simple combination of a gravity infusion with an infusion pump is given. Much more complex infusion regimen are possible.



1. Gravity infusion
2. Measurement of the central venous pressure
3. Drip chamber
4. Roller clamp
5. Back-check valve
6. 20 cm below the heart level
7. Siphon
8. 3-way stopcock
9. Y-piece
10. Infusion pump

2.1 Potential hazards associated with combinations of unmonitored gravity infusions

The desired drip rate is adjusted manually using the roller clamp²⁾ and must be checked and corrected regularly as the drip rate can change over time.

The occurrence of ruptures can be ruled out, since there is no additional pressure build-up that takes place.

Under certain pressure conditions, air infusions can result from the line running empty.

However, the user can prevent these reliably and easily by suspending the infusion lines in a loop (siphon) at least 20 cm below the patient's heart level.

With gravity infusions, there are no monitoring features. Occlusions at the patient's access site or in the tubing system can only be identified through monitoring by personnel or equipment.

Potential hazards associated with combinations of unmonitored gravity infusion can be:

- **Inaccurate delivery** (always possible while infusion is running)
Over- or underdosage caused by changing pressure conditions during the infusion. The changes in flow are particularly great when new infusions are added to the infusion regimen or existing ones are "unhooked".
Consequence: Changing dosages
- **Unnoticed interruption** (in case of occlusion)
in the infusion due to a lack of monitoring by the user or the monitoring equipment.
Consequence: Underdosage
- **Return flow** (in case of occlusion)
The infusion fluid does not flow to the patient, but from the connection site (for example with multiple stopcock systems) of the single infusion back in the direction of the infusion container.
Consequence: Underdosage
- **Drug bolus** (in case of occlusion)
Consequence: Overdosage because:

When eliminating the occlusion, the drug bolus that has collected during the return flow is flushed to the patient!

Since mostly non-critical solutions are infused by gravity, the consequences caused by the above-mentioned problems tend to be minor. They are taken into account when this form of administration is selected or are covered by having personnel monitor the infusion.

Monitoring equipment or a regulator for gravity infusions add enhanced safety, but the use of more equipment can lead to an undesirable increase in the number of alarms.

2.2 Potential hazards associated with pump combinations

In many therapy regimens, the use of pumps is indispensable.

By applying the appropriate type of pressure build-up, infusion and injection pumps can maintain constant delivery even during fluctuating counterpressures. Such pumps are equipped with monitoring systems that sound an alarm whenever fluctuations in flow, air in the system and impermissible pressure build-up due to occlusions occur.

When flow stops due to an occlusion, some time will pass before the increase in pressure is identified and an alarm is triggered (alarm delay time).

During of the pressure buildup, the elastic tubing system stretches and compensates for the additional volume (bolus volume).

The alarm delay time roughly can be calculated with the following formula:

$$\text{Max. alarm delay time} = \text{bolus volume} / \text{delivery rate}$$

From a medical viewpoint, an alarm delay time of less than 5 min is desirable. At low delivery rates, many of the single pumps currently on the market are not technically equipped to meet this requirement, as the following example will illustrate:

When a bolus volume of 1 ml is created by a pressure build-up, a conventional pressure recognition system (drop or force) pre-set to a delivery rate of 1ml/h will require one hour before an alarm is triggered.

When several combinations of pumps are connected together, the bolus volumes and alarm delay times may be higher than with single infusions. In the event of unacceptable alarm delay times, another monitoring method must be used to watch the infusion, for example a monitoring system.

In case highly potent drugs are used, not only the stop in medication can be critical but also the bolus that may get to the patient when the occlusion is released.

The following table of alarm delay times and bolus volumes under different combinations and delivery rates the following may be used as an example:

Delivery Rates	Bolus Volumes	Alarm Delay Times
6 Infusomat® fmS 6 x 50 ml/h = Total Delivery Rate 300 ml/h 6 x 150 ml/h = Total Delivery Rate 900 ml/h	2.4 ml 2.6 ml	30 s < 30 s
12 Perfusor® fm 12 x 1 ml/h = Total Delivery Rate 12 ml/h 12 x 10 ml/h = Total Delivery Rate 120 ml/h	11.6 ml <u>2.9 ml</u> 12 ml <u>3.6 ml</u>	69 min <u>18 min</u> 7 min <u>2 min</u>
6 Infusomat® fmS and 6 Perfusor® fm 6 x Infusomat® fmS 6 x 50 ml/h = 300 ml/h 6 x Perfusor® fm 6 x 1 ml/h = 6 ml/h Total Delivery Rate = 306 ml/h 6 x Infusomat® fmS 6 x 150 ml/h = 900 ml/h 6 x Perfusor® fm 6 x 1 ml/h = 6 ml/h Total Delivery Rate = 906 ml/h 6 x Infusomat® fmS 6 x 50 ml/h = 300 ml/h 6 x Perfusor® fm 6 x 10 ml/h = 60 ml/h Total Delivery Rate = 360 ml/h 6 x Infusomat® fmS 6 x 150 ml/h = 900 ml/h 6 x Perfusor® fm 6 x 10 ml/h = 60 ml/h Total Delivery Rate = 960 ml/h	9.7 ml <u>3.5 ml</u> 9.9 ml <u>4.9 ml</u> 8.9 ml <u>3.3 ml</u> 9.9 ml <u>4.7 ml</u>	2.0 min <u>30 s</u> 30 s <u>11 s</u> 2.0 min <u>30 s</u> 30 s <u>11 s</u>

The measurements are examples of possible configurations – the values are approximate values. They have been measured with Infusomat® fmS and Perfusor® fm. Other B.Braun large volume pumps like Infusomat® Space result in analogue values as the ones for Infusomat® fmS. Other B.Braun syringe pumps like Perfusor® compact/S or Perfusor® Space result in analogue values to the ones of Perfusor® fm. The pressure-level settings for Infusomat® fmS always have been level high which corresponds to level 9 in Infusomat® Space. The pressure-level settings for Perfusor® fm have been either 1 (underlined value) or 9 (not underlined value).

Delay of reaction by the user can increase bolus volumes!

When eliminating occlusions, it is important to ensure that the bolus does not reach the patients. The bolus can be reduced by creating an outside opening in the tubing system or reduced through the pump (follow the instruction manual included with the pump). When the administration regimen permits, a reduction in occlusion alarm pressure settings can shorten the alarm delay times and lower bolus volumes.

When parallel infusions with pumps are used, pressure-resistant tubing systems and components are indispensable for preventing ruptures. The pressure resistance value of 2 bar required by current standards is often not sufficient. Older pumps, in particular, may tend to build up higher pressures. All components (stopcocks, extension lines, filters etc.) employed within the pressure range must be able to withstand the occlusion alarm pressure of the pumps. (Please observe the technical specifications of the pump!).

Air infusion is prevented by the pump's monitoring equipment.

Occlusions can be identified only when all pumps are in operation and their monitoring systems have the chance to react.

When individual pumps in the infusion regimen are turned off, the roller clamp therefore must be closed and/or the infusion lines locked off at the connection site in order to prevent back flow into the infusion bottle or ruptures.

Back-flow can develop when the occlusion pressure of the pump that has been taken out of operation is overcome because the pumps still in operation build-up pressure. An alarm alert is not possible since the alarm system of the switched-off pump is not activated.

Such a situation can even lead to ruptures in pressure-resistant tubing systems, since pressure resistance can only be guaranteed for the patient line downstream from the pump button.

Pump-driven parallel infusions can only be regarded as safe when extended alarm delay times are taken into account and handling safety rules and regulations are followed.

2.3 Potential hazards when unmonitored gravity infusions are combined with pumps

An especially high hazard potential is posed when unmonitored gravity infusions are combined with pumps.

If there is an occlusion in the patient line, the pump cannot identify occlusions because no pressure buildup takes place in the system. The reason for this is that return flow from the pumps in the gravity infusions occurs. The patient is not receiving any medication for the duration of return flow.

When the occlusion is eliminated, a drug bolus can be the result. Frequently, the pumps are utilized to administer solutions containing highly potent drugs. Therefore, over- or underdosage can have life-threatening consequences for patients.

As with pure gravity systems, changes in delivery rates or pressure changes can lead to inaccurate delivery of the gravity infusion.

The user can prevent air infusion caused by the gravity infusion running empty by installing the connection site between gravity and pump infusion below the patient's level (syphon) or by installing monitoring equipment that stops the infusion from running empty, early, in the drip chamber.

In all cases, ruptures should be prevented through the use of pressure-resistant components, also when gravity infusions are employed. Under certain circumstances, P-tubing systems³⁾ according to the standard may not be sufficient!

It is best to avoid the combination of pumps and unmonitored gravity infusions. If this is not possible, then intensified monitoring is vitally essential.

3. Utilizing technical assistive devices to enhance safety

Infusions delivering vital and crucial drugs must be subject to continuous monitoring. As a rule, this monitoring must be carried out by medical personnel, but may be supported by technical assistive devices.

Problems will be encountered with all combinations of the unmonitored gravity infusion, since occlusions cannot be recognized and/or the alarm system functions on the pumps are deactivated.

Beyond the rules and regulations the user must observe, technical safety precautions can be implemented after the costs and benefits have been weighed. Not all possible types of equipment and devices produce the desired safety gain. For the user, they can also add to making the infusion regimen even more complicated, usually by an increase in nuisance alarms.

3.1 Multilumen catheters

Multilumen catheters can solve these problems of parallel infusions when gravity and pump infusions are set up on separate lumens. However, they may not offer an entirely satisfactory solution because they increase the complication rates for patients. Therefore, they are mostly used to prevent incompatibility reactions between different drugs.

3.2 How to avoid passive back-flow with back-check valves

Back-check valves installed in the tubing system can prevent return flow and any resulting drug boluses. When gravity and pump infusions are combined and a back-check valve is installed in the gravity line, the alarm systems on the pump can not identify occlusions.

Do note that air infusion cannot be prevented by the use of back check valves.

Unfortunately, some of the back-check valves currently on the market are not perfectly safe, particularly at low flow rates and therefore it is inadvisable to use them. The reliable and safe closure of the valve additionally can be impaired when particles become lodged or components stick. In such a case the user is suggestively given a false sense of safety and relies on the valve, but has no opportunity to recognize when malfunctions occur.

Whenever the reliable function of valves cannot be guaranteed, it is not advisable to use them.

3.3 Active monitoring systems

3.3.1 For gravity infusions with drop sensors

One possibility for monitoring gravity infusions is to record the drip rate with a drop sensor, which recognizes any inaccurate delivery and sounds an alarm in the event of an occlusion. The drop sensor-driven monitoring prevents air infusions that might develop from the infusion container running empty.

There are 3 different types of devices available in some markets:

Drop counters

sound an alarm when the drip rate deviates from the target value, but do not intervene in the delivery. They must tolerate very great deviations from the target rate (+25 up to -50%) without sounding an alarm because the drip rate on gravity infusions regulated by a roller clamp changes over time.

Gravity flow regulators

are electromechanically operated tubing clamps. They actively readjust the drip rate. If readjustment is no longer possible, an alarm is triggered quickly and the infusion lines are shut off, thereby preventing any back-flow. The alarm limits are much narrower than with the drop counters.

Infusion control devices

function like drop counters with access to the pumps. Monitoring of the gravity line with pump stop is possible if desired.

All three of these types of devices offer reliable and safe monitoring of gravity infusions and guarantee occlusion recognition, prevention of air in-line and ruptures. However, their prices and performance capabilities vary.

One negative feature is the frequent nuisance alarms that are triggered by changes in flow. Every gravity infusion involved in the infusion regimen needs to have its own drip monitor which makes it a cost multiplier.

3.3.2 Bedside pressure recording devices

When connecting infusion lines to the patient's access site, the devices measure the prevailing pressure there, which is normally below the hydrostatic pressure. The pressure switch requires special single-use products. When an occlusion occurs between pressure switch and patient's access site, the pressure rises, and the pressure switch can sound an alarm.

Such devices feature pressure alarm limits that can be set by the user. If the alarm threshold is set too high, it can happen that no alarm is triggered, specifically when the hydrostatic pressure is lower than the alarm pressure. When combinations of gravity and pump infusions are used, back-check valves can provide added security respectively are necessary to let the devices work.

When it is possible to reliably prevent the return flow in the gravity infusion, the pressure that is then built up by the pumps will cause the pressure switch to trigger an alarm, even if the alarm threshold is set to the maximum. Unfortunately, the known disadvantages of back-check valves tend to counteract this solution to the problem at present.

The pressure switch cannot recognize the pressure build-up if occlusions occur above the sensors.

If the pressure alarm limits are set too low, pressure surges caused by the patient (movements or coughing for example) can trigger false alarms.

Under consideration of the above limitations, the devices are only suited for occlusion recognition under certain conditions and cannot identify air.

4. Summary and conclusion

The state-of-the-art can be summed up as follows:

- Infusion therapy, particularly with parallel infusions, is necessary, but not free of risk.
- Infusions with vital and crucial drugs and pressure infusions demand continuous monitoring which, as a rule, must be carried out by medical personnel. Assistive equipment can be utilized as support.
- There is no universal answer, but a number of application rules and technical solutions that, if applied, will produce an adequate level of safety.
- Responsibility always lies with the user.
 - Depending on the situation, each user must decide on the selection of the most suitable infusion system.
 - Technical safety equipment cannot replace individual monitoring by the user.

- 1) Terms like multiple, mixed or multi-way infusion are similarly common.
- 2) A roller clamp is normally also referred to as a flow regulator.
- 3) p = pressure resistant up to 2 bar.

Parallel infusion checklist

- When combinations are required, the delivery type most suited to the intended application must be chosen
- Combinations of uncontrolled gravity and pressure infusions should be best avoided since they harbor the greatest hazard potential. If it cannot be avoided, then only under the continuous supervision by personnel and monitoring equipment.
- Never use technical monitoring equipment indiscriminately. Weigh the costs and benefits of each individual application. Technical safety equipment is no substitute for monitoring by the user.
- To prevent air infusion, the access site should be positioned below the patient's heart level or the tubing looped like a siphon.
- Readjust all gravity infusions whenever there are changes in pressure or flow patterns in the system.

When pumps are involved:

- Use pressure-resistant tubing system and accessories (maximum shut off pressure is critical, P-tubing systems are often not sufficient!).
- When pumps are combined together, it is best to use the pumps of the same type and/or pumps with the same occlusion pressures. If the application permits, low pressure settings are to be preferred.
- Observe overly large bolus volumes and alarm delay times.
- When critical drugs are used, intensified monitoring is indicated; it is imperative that the user reacts immediately to any alarm!
- When pumps in the infusion regimen are switched off, close the roller clamp or 3-way stopcock at the connection site in order to prevent any unnoticed back-flow.
- When a pump is temporarily switched off, there is a danger a bolus resulting from an accumulation of drug concentrations at reduced flow.

Issued by:

B. Braun Melsungen AG
D-34209 Melsungen