BTM - Blood Temperature Monitor

Improved quality of haemodialysis as a result of individualised temperature control
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Intradialytic complications – still a problem today?

Even today, the dialysis treatment is frequently interrupted by hypotensive events. Such events occur during up to 20% of all treatments, in some cases even more frequently [1, 2]. Moreover, patients complain of cramps, nausea and dizziness and some patients may even lose consciousness during treatment (Fig. 1).

The measures which are then required include, e.g. discontinuation of ultrafiltration or the administration of hypertonic solutions: it may even become necessary to prematurely terminate the dialysis session.

These undesirable effects and the interventions required not only interfere with the operation of the dialysis unit, but also increase material requirements.

Such events are even more serious from the point of view of the patient, as they not only involve considerable impairment of the quality of treatment, with symptoms such as nausea or tiredness expanding also into the interdialytic interval. Moreover, all interventions undertaken, such as the reduction of blood flow or premature discontinuation of treatment, also mean that the aims of treatment – detoxification and fluid removal – are placed at risk. Discontinuation of ultrafiltration and administration of hypertonic solutions make it difficult to achieve specified dry weight and can have long term hypertensive effects.

In addition, there can be long term consequences if hypotensive episodes occur frequently, such as damage to cardiac and neural tissue, acceleration of the loss of residual renal function and possibly an increased risk of morbidity and mortality [1, 3].

Although the technical improvements introduced in recent decades have led to a reduction in the frequency of hypotensive episodes during haemodialysis, the problem is still present today. One reason for this is that in the group of dialysis patients, as in the population as a whole, the average age and the proportion of individuals with cardiovascular disorders are constantly increasing.

Fig. 1: Hypotensive episodes, cramps and other symptoms can occur in up to 50% of dialysis sessions [2]

Fig. 2: Patient and therapy related factors contribute to the development of intradialytic hypotension
In addition to these factors, there are the pathophysiological problems characteristic of patients with renal insufficiency and the various parameters relating to the haemodialysis treatment which need to be taken into account (Fig. 2).

It has been demonstrated in epidemiological and clinical studies that there is an increased risk of hypotensive episodes during dialysis particularly in patients of advanced age, patients with accompanying cardiovascular disorders (such as cardiac arrhythmia, hypotension, left ventricular hypertrophy, diastolic dysfunction) or diabetes mellitus (peripheral and autonomic neuropathy), patients in whom there is an interdialytic increase in weight of more than 3% of dry weight and in anephric patients [3].

Fluid removal is the main factor that can cause hypotension during dialysis. At a haematocrit value of 33%, an average blood volume of 4.5 litres is equivalent to approximately 3 litres of plasma. Assuming an average weight gain corresponding to 1.5 litres per day or approximately 3 litres over 2 days, the volume removed during a dialysis session is equivalent to the total plasma volume. This removal of fluid is compensated by plasma refilling from the interstitial tissues, which is determined by various factors, such as the extent of overhydration or the sodium concentration in the dialysate and, in consequence, in the blood. As the plasma refilling does not occur at the same rate as the removal of fluid by the dialyser, hypovolaemia is induced. In order to ensure that a stable blood pressure is maintained under these circumstances, the body has developed various compensatory regulatory mechanisms which generally allow dialysis treatment to be completed without problems arising.

Hence, cardiovascular reactions, such as an increase in heart rate, increased contractility of the cardiac muscle and/or an increase in peripheral resistance can, to a limited extent, counteract the effects of hypovolaemia and prevent the development of hypotension. Unfortunately, the accompanying cardiovascular complications in many patients mean that these regulatory mechanisms are impaired, so that the risk of hypotensive episodes is further increased [1].

Pathophysiological factors affecting dialysis patients, but also the use of inadequate treatment parameters, can lead to hypotension during dialysis.
Hypovolaemia and body temperature

The body's thermoregulatory mechanisms, however, are superimposed on the physiological reactions to volume reduction. The purpose of thermoregulation is to maintain a constant core body temperature. Excessive heat can be removed from the body if peripheral vascular resistance is reduced to increase blood perfusion in the capillary vessels of the skin. In the opposing situation, in hypothermia, there is an increase in peripheral vascular resistance in order to reduce the blood perfusion of the skin and thus the release of thermal energy.

In the case of dialysis patients, thermal energy can also be released or taken up by the extracorporeal circulation (Fig. 3).

These processes of temperature regulation are, however, superimposed by volume regulation. The body reacts to volume reduction as a result of fluid removal with increased peripheral vascular resistance in order to stabilise central blood volume and blood pressure. The reduction of cutaneous blood flow means that the radiation of thermal energy from the skin is also reduced.

Not only as a result of this, but also because of increased metabolic production of thermal energy and the potential supply of thermal energy via the dialysate during haemodialysis, there is an increase in core temperature [4]. When this increase reaches a critical point, the body reacts by dilating skin vessels in order to eliminate the excessive heat from the body by increasing peripheral blood flow. This sudden reduction in peripheral vascular resistance can very frequently trigger a fall in blood pressure.

Early studies demonstrated that the body was very sensitive to even slight shifts in temperature. The standard range of temperature for dialysis fluids (37–37.5 °C) frequently causes an increase in body temperature of 0.3–0.5 °C [5, 6, 7, 8]. This can be a particular problem when hypothermal patients (body temperature prior to dialysis <36.5 °C) are exposed to “standard dialysate temperatures” of 37 °C [9]. Even a very slight increase in temperature has led to a marked drop of blood pressure (Fig. 4) and an increase in the frequency of staff interventions (Fig. 5), in contrast to treatments in which body temperature was maintained at a constant level or was slightly reduced by use of a cooled dialysate (Fig. 4, 5) [7, 10].

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![Fig. 3: During dialysis thermal energy can be lost or supplied via the extracorporeal circulation](image)

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![Fig. 4: A slight increase of the core body temperature can cause a marked blood pressure drop](image)
With an increase in body temperature of less than 1 °C, the fall in blood pressure was double that recorded during treatments in which body temperature was kept constant [5]. This sensitivity to temperature is particularly pronounced in patients known to be prone to hypotension [11].

In view of these observations, it is clear that the stabilisation of core body temperature is one of the basic requirements of haemodialysis treatment. Excessive body heat, which can be eliminated via the skin only to a limited extent due to volume-induced vasoconstriction, should thus be eliminated by means of the extracorporeal blood circulation. This is dependent, however, on the temperature difference between blood and the dialysate and can vary considerably, as there can be great differences in predialysis body temperature, not only between individual patients, but also from one treatment to another. Many patients are hypothermal at start of dialysis, i.e. their body temperature is less than 37 °C. The lower the body temperature on initiation of dialysis, the greater the increase in temperature during treatment (Fig. 6) [12]. In addition, there are very wide variations in heat production and body temperature during dialysis between individual cases.

Active regulation of body temperature is not possible merely by use of a dialysate at a specific fixed temperature. What is required is a regulation of temperature that takes into account the predialytic body temperature of the individual patient, and the course of body temperature related to volume regulation, and that variably and automatically adjusts to the actual temperature development during treatment (Fig. 7). Such regulation is possible using the Blood Temperature Monitor (BTM).
How does the BTM register and regulate individually body temperature?

The dialyser, in which blood and dialysate circulate in a counterflow, is an ideal heat exchanger. Dependent on the temperature of the blood and the dialysate, the blood in the dialyser either releases or takes up thermal energy. Measurements have shown that the blood absorbs thermal energy when the dialysate temperature is 37 °C with a consequent rise in body temperature by an average of 0.3 °C, while with a dialysate at a temperature of 34 °C, the patient releases thermal energy with a reduction in body temperature by 0.7 °C [6]. The increase in body temperature which is observed with dialysates at standard temperatures has an unfavourable effect on cardiovascular stability. One way of avoiding this increase in temperature is to reduce the temperature of the dialysate, but when this method is used patients frequently complain of a sensation of coldness. Cold-induced shivering may even occur, a physiological reaction to maintain body temperature by increasing metabolism and heat production [6, 9, 13].

The situations described above are undesirable. It should thus be ensured that the least possible effects on body temperature occur during dialysis treatment.

Active control of blood temperature is easy to be performed with the Blood Temperature Monitor (Fig. 8). The device has two sensors which non-invasively monitor arterial and venous blood temperature in the extracorporeal circulation. On the basis of these recordings the corresponding fistula temperatures are calculated. Arterial blood temperature is determined by body temperature, venous temperature by the temperature of the dialysate.

By altering the temperature of the dialysate, the temperature of the venous blood re-entering the fistula can be adjusted by means of heat transfer. The higher the venous temperature in comparison with arterial temperature and the higher the actual blood flow rate, the greater the amount of thermal energy transferred to the blood per time unit. The required dialysate temperature is calculated on the basis of the results of temperature measurement, actual blood flow rate and several other constants.

The BTM provides two basic methods of thermal regulation (Fig. 9).

With the one option, thermal energy control (E control), it is possible to control the supply of thermal energy to and from the extracorporeal circulation. If a neutral temperature balance is required, thermal energy should neither be supplied nor removed and the measured temperatures of the arterial and venous fractions of the extracorporeal blood circulation should be identical.
In order to achieve this, the dialysis machine continuously adjusts the temperature of the dialysate to the temperature recorded by the arterial sensor. As the arterial temperature increases during dialysis, it is not possible to control body temperature using this method.

From the therapeutic point of view, E control at a setting of 0 kJ/h is advisable if it is desirable to exclude influencing thermal energy balance in the extracorporeal circulation.

In clinical practice, however, thermal energy regulation is generally less important than **body temperature control (T control)** with the BTM.

This option allows active regulation of body temperature. This is more advantageous in physiological terms, as any increase in temperature induced by hypovolaemia, and thus the risk of hypotension, can be avoided.

In T control, the device measures the current temperatures of arterial and venous blood in the sensor heads and calculates the corresponding fistula temperatures, taking into account the potential loss of thermal energy in the blood tubing system. In order to determine core body temperature, the blood recirculation must also be taken into account. This is measured using the BTM thermodilution technique.

The body core temperature at start of the treatment, which is used as the target temperature for active regulation, is calculated on the basis of total blood recirculation and various system parameters (actual blood flow rate, assumed ambient temperature set usually at 23 ºC, thermal conductivity of the blood tubing system and the distance between the patient and the sensor). Measurement and calculation are continually repeated during treatment and the temperature of the dialysate is adjusted if body temperature rises or falls to ensure that the preset core body temperature is maintained. Although in most cases maintenance of a constant core temperature will be required (∆T = 0 ºC), it is also possible to achieve an increase or reduction of core temperature within certain limits, e.g. in case of hypothermia or high fever.

Heat exchange in the extracorporeal circulation and thus body temperature can be actively controlled using the BTM.

**The limits of temperature regulation**

The BTM can regulate the temperature of the dialysate only within a narrow physiological range, generally 35 – 38 ºC. This avoids the risk of undercooled or overheated blood being supplied to the patient. It also means that an unexpected change in the body temperature of the patient, such as development of fever, does not remain undetected. In such a case, the BTM would possibly be unable to achieve the set target (e.g. maintenance of a constant body temperature), but dialysate temperature would remain within a physiological range.

Temperature alarm limits (set to temperatures outside the upper and lower limits of the BTM itself) which have been installed in the dialysis machine also prevent the patient being exposed to dialysate at inappropriate temperatures.
The use of the BTM in clinical practice

As numerous studies have shown, an increase in body temperature during dialysis has unfavourable effects on the cardiovascular stability of the haemodialysis patient. The effects of active control of core body temperature on cardiovascular stability using the BTM, which prevents undesirable rises or falls in temperature, have been investigated in several clinical studies [10, 14].

This aspect was investigated in a multicentre study conducted in 27 European dialysis centres [14]. A total of 95 patients, who frequently suffered hypotensive episodes during dialysis, received either dialysis with constant body temperature regulation (in T control: temperature difference; $\Delta T = 0$ °C) or with neutral energy balance in the extracorporeal circulation (E control: $\Delta E=0kJ/h$, i.e. with identical arterial and venous temperature) for a period each of 4 weeks.

The results of this study confirmed that it was necessary to reduce the temperature of the dialysate during treatment and thus eliminate thermal energy from the patient in order to maintain the body temperature measured by the BTM at start of treatment (T control) (Figs. 10, 11, 12a).

When in the extracorporeal circulation only the supply or removal of thermal energy was regulated (E control), however, there was an increase in body temperature (Fig. 12b), which was accompanied by increasing dialysate temperature.

This means that body temperature increases irrespective of whether thermal energy is supplied via the extracorporeal circulation – probably as a result of the vasoconstriction induced by volume reduction and the resultant decrease in heat dissipation from the skin.
In the prephase to this study, in which patients received treatment using dialysates at the temperatures routinely employed at the centres, and in the phase in which the exchange of thermal energy in the extracorporeal circulation only was regulated, hypotensive episodes requiring treatment occurred on average in 50% of dialysis treatments. This rate was significantly reduced to 25% with active temperature regulation and maintenance of a constant core temperature using the temperature control function of the BTM (Fig. 13).

At the same time, blood pressure and heart rate were more stable when body temperature remained constant as a result of active temperature regulation.

It was also demonstrated in this study and others, that the dialysis dose, measured as Kt/V, was not influenced by temperature control [10, 14].

Targeted regulation of core body temperature improves cardiovascular stability and thus also the quality of treatment of the patient.

**Targeted regulation of core body temperature significantly improves cardiovascular stability and thus also the quality of treatment of the patient.**

![Fig. 13: The frequency of treatments with symptomatic hypotension can be reduced by active control of body temperature with the BTM](image-url)
Recirculation

If the blood flow to the fistula is lower than the blood flow rate set for the extracorporeal circulation, it is possible that purified venous blood may pass back through the fistula in the opposing direction and re-enter the extracorporeal circulation. As this means that the blood does not pass through the capillary system of the body, it will not be loaded with uraemic toxins. As a result, the toxin concentration in the blood reaching the dialyser and hence the purification efficiency of the treatment are reduced. The dialysis dose achieved with each treatment is reduced and, over the long term, this can result in increased morbidity in the patient.

In addition to fistula recirculation, cardiopulmonary recirculation can also occur. In this case, the right ventricle, lung and left ventricle represent the recirculation pathway of the purified blood. Cardiopulmonary recirculation also leads to a reduction of clearance.

Using the BTM, it is possible to determine the extent of recirculation by means of a non-invasive temperature bolus technique (see page 15). This method can be used to detect both fistula recirculation and cardiopulmonary recirculation. The value for recirculation determined by the BTM (given in %) reflects total recirculation and is equivalent to the percentage of extracorporeal blood recirculating in the fistula or cardiopulmonary circulation.

If the value for recirculation is low (<10 %), this is probably attributable to unavoidable cardiopulmonary recirculation only.

If the value for recirculation is high (>20 %), there is probably considerable fistula recirculation. In this case, it should be ensured that the cannulas are appropriately positioned and that the tubes have not been incorrectly connected. If there are no such errors, the fistula should be examined for the presence of any possible stenoses.

If recirculation is in the range 10 - 20 %, it is possible that the patient has a very high rate of cardiopulmonary recirculation or that there is fistula recirculation. In order to determine which of these two alternatives applies, the blood flow should be increased or reduced by 100 ml/minute, and the recirculation re-measured. If there is only a slight change in recirculation, cardiopulmonary recirculation is probably the cause. If, on the other hand, there is a marked change in recirculation (>10%), it is more likely that fistula recirculation is present.

It should be borne in mind whenever recirculation is determined that the efficiency of dialysis is reduced and it is advisable to consider prolongation of treatment.

Using the BTM, it is possible to measure total blood recirculation with a non-invasive technique and thus detect vascular problems which could reduce the efficacy of dialysis.
A brief overview of the operation of the BTM

The BTM is easy to operate (Fig. 14a, b) and requires only a few parameters to be set for routine dialysis treatment. No special consumables are required for operation.

Similarly, the venous line from the venous bubble trap is inserted into the lower venous sensor. The length of tube between sensor head and fistula should be approximately 1.5 m (including the tube length used to connect to the fistula needle). It should be ensured that tubes are not covered e.g. by bed sheets.

Prior to setting a regulation mode, the required dialysate temperature is set in the dialysis machine in accordance with manufacturer’s instructions. When the BTM is operative, it regulates temperature in accordance with the selected mode; if there is a malfunction of the BTM or the operation of the BTM is prematurely terminated, the temperature setting of the dialyser is automatically used.

Regulation of thermal energy balance in the extracorporeal circulation

In order to set the BTM to regulate thermal energy balance in the extracorporeal circulation, press “E Set”. The energy flow rate (in kJ/h) is set to the required value using the arrow keys. The energy flow rate can be set within a range of -500 to +200 kJ/h. If a positive value is selected, thermal energy is supplied to the patient, if the value is set to 0, the BTM maintains a neutral thermal energy balance in the extracorporeal circulation, while at a negative value, thermal energy is withdrawn from the patient. Confirm with the “Enter” key.

The value for thermal energy displayed should be reset to “0” by pressing both arrow keys so that the energy balance of each dialysis treatment can be exactly measured.

When the “Enter” key is pressed, regulation of extracorporeal thermal energy balance is initiated. An LED on the “E Set” key lights up to confirm that this mode is operational.

Thermal energy balance regulation can be ended at any time by again pressing the key “E Set”.

A short overview of the operation of the BTM is provided below. Please note that the BTM should only be used in practice after the operator's manual has been studied in detail and the operator has received appropriate instruction.

Thermal energy and temperature regulation with the BTM

Connection of blood lines and initiation of treatment

As the sensor heads are flexible to some extent, blood tubing systems with an external diameter of 6.5 - 7.05 mm can be used with the BTM. It is important to ensure that both arterial and venous blood lines are of the same diameter.

The arterial line is inserted into the upper, arterial sensor head and then connected to the arterial blood pump and to the dialyser and dialysis machine as usual.
Regulation of body temperature

In order to set the BTM to regulate body temperature, press “T Set”. Body temperature adjustment (in °C/h) is set to the required value using the arrow keys and the setting is confirmed by pressing the “Enter” key. Body temperature adjustment can be set within a range of -0.50 to +0.25 °C/h. At a positive value, body temperature is increased, at a negative setting, body temperature is decreased. If the value is set to “0”, body temperature is maintained at a constant level.

If only the thermal energy balance of the ongoing dialysis treatment is to be measured in this mode, the value for the energy balance displayed should also be reset to “0” by pressing the two arrow keys.

When the “Enter” key is pressed, regulation of body temperature is initiated. An LED on the “T Set” key lights up to confirm that this mode is operational.

Body temperature regulation can be ended at any time by again pressing the key “Select T mode”. In this case, the system automatically switches over to the dialysate temperature previously set at the dialysis machine.

Display of thermal data

Various thermal data can be displayed using the keys of the upper row of the panel.

- **T Art**: Arterial fistula temperature in °C, i.e. the temperature of the blood at the entry from the fistula to the arterial needle.

- **T Ven**: Venous fistula temperature in °C, i.e. the temperature of the blood in the venous needle directly prior to re-entry into the fistula.

- **E**: Thermal energy flow rate in kJ/h, i.e. the quantity of thermal energy supplied to or withdrawn from the patient via the extracorporeal blood circulation per time unit.

- **E**: Total thermal energy balance in kJ, i.e. the quantity of thermal energy supplied or withdrawn from the patient since the commencement of treatment or resetting of the energy balance. A negative value means that thermal energy has been withdrawn from the patient.

- **Result (press twice)**: Current core body temperature (displayed for 5 seconds) as calculated by the BTM. This can only be displayed if recirculation has been previously determined. In temperature control mode, this occurs automatically (at start, then at hourly intervals and whenever there are larger variations in blood flow). In thermal energy regulation mode, this must be initiated manually.

- **Result (press five times)**: Current temperature of the dialysate (displayed for 5 seconds).

Termination of thermal energy or temperature regulation

The BTM automatically recognises the completion of the dialysis treatment; at this point, the regulation function is ended and any ongoing recirculation measurement is terminated.

If it is necessary to prematurely terminate BTM operation (e.g. at the wish of the patient), this can be accomplished simply by pressing “T Set” or “E Set” as appropriate, or removing the blood lines from the sensor heads. This is automatically recognised by the BTM which then switches over to the dialysate temperature setting of the dialysis machine.
Recirculation measurement

For the purpose of recirculation measurement, the BTM induces a brief (positive or negative) temperature bolus, characteristically in the range ±2.5°C, for 2.5 minutes via the dialysate (Fig. 15). This temperature bolus is transferred to the venous blood and hence via the venous sensor head to the fistula. This bolus is partially transported, via cardiopulmonary and fistula recirculation to the arterial line, where the attenuated bolus is detected by the arterial sensor head. The relation of the temperature boluses measured by arterial and venous sensor heads is equivalent to the percentage recirculation of blood flow.

A recirculation measurement can be initiated at any time during the dialysis session. The regulation mode selected for the operation of the BTM is briefly interrupted and automatically restarted on completion of the recirculation measurement.

To start recirculation measurement, press the key REC %. When the measurement is completed, the percentage recirculation is displayed for 30 seconds. The result can be redisplayed in the following 30 minutes using the key Result (press once). Recirculation measurement requires on average 5 - 6 minutes.
Use of the BTM in other treatment modalities

**Online Clearance Monitoring OCM®**
All functions of the BTM can be used in combination with the option OCM®. Both measurement cycles of the BTM and OCM® are synchronised, thus permitting an optimal monitoring on the efficacy of the running treatment.

**Blood Volume Monitor BVM**
The BTM can be used simultaneously with the BVM, offering an automatic and individually adapted control of body temperature and blood volume in order to prevent the occurrence of Symptomatic Hypotension.

**Single-Needle dialysis**
It is not possible to use the BTM during Single-Needle dialysis.

**On-line Haemodiafiltration**
The BTM can be used during on-line haemodiafiltration with the ONLINEplus® system, irrespective of whether a pre- or post-dilution treatment is provided.

**Online Haemofiltration / isolated ultrafiltration**
As there is no countercirculation of blood and dialysate during these procedures, it is not possible to regulate extracorporeal thermal energy balance or body temperature with the BTM. However, fistula temperatures can be measured and the thermal energy balance calculated on this basis.

**Sodium profiles and UF profiles**
The BTM can be used in combination with all Sodium and UF profiles.

**Central venous catheter**
As a certain heat exchange can occur along double lumen central venous catheters, the BTM should only be used in patients with central venous catheters when two separate cannulas are used.
**Frequently asked questions**

**Can temperature regulation with the BTM be interrupted during on-going treatment?**

The temperature regulating functions of the BTM can be stopped at any time during on-going treatment. However, it is then not possible to continue with temperature regulation after a restart, as the BTM uses the temperature at restart as the baseline for temperature regulation. Hence, the current temperature rather than the original temperature on commencement of treatment is taken as target temperature by the BTM after a restart. Thermal energy regulation can be continued, as this is controlled on the basis of the current arterial and venous temperatures measured by the sensor heads.

**Can I change the BTM settings during operation?**

It is possible to adjust set target parameters during operation, i.e. for thermal balance in the extracorporeal circulation or control of body temperature, however, in the latter case, an ongoing regulation is interrupted.

**Can patients eat or drink during operation of the BTM?**

It is known that eating and drinking during dialysis can increase the risk of hypotensive episodes, so that dialysis patients with unstable blood pressure are advised not to do so. As during active temperature regulation with the BTM the cardiovascular stability may be improved, it could be tested under close monitoring whether patients tolerate nutritional intake better under these conditions.

**Is it possible to detect fever if the BTM is counteracting the temperature regulation mechanisms of the body?**

The BTM adjusts dialysate temperature only within a very narrow range, generally 35–38°C. Hence, there is no masking of any marked increase in body temperature e.g. due to a pyrogenic reaction while the BTM is active. On the other hand, this might mean that the BTM does not achieve the set target of temperature regulation or energy balance.

**Do patients experience a sensation of coldness during temperature regulation with the BTM?**

There have been only very rare reports of patients experiencing a sensation of coldness during temperature regulation and stabilisation of body temperature with the BTM. In contrast with systems in which a dialysate cooled to a fixed temperature is used, there is no abrupt cooling of the blood, but blood temperature is maintained at a constant level due to the individual adjustment of the temperature of the dialysis fluid.

**Can the BTM also be used during hot weather?**

The BTM is preset to operate at a room temperature of 23 °C. The device uses this temperature when calculating the potential loss of thermal energy along the blood lines between sensor head and fistula. The effects of variations in room temperature of ±2 °C are negligible. If there are consistently larger deviations in ambient temperature, a different standard temperature should be selected for BTM operation in the set-up menu.

**Why is there an increase in the extent of recirculation during treatment?**

During treatment, there is usually a reduction of relative blood volume and thus a decrease in cardiac output. This can lead to an increase in the value determined for recirculation during treatment. It is thus advisable to conduct measurement of recirculation during the first 30 minutes of a dialysis treatment.

**How frequently should recirculation be measured?**

It is advisable to measure recirculation as frequently as possible: if necessary, during each treatment. This allows close control of the dialysis procedure, so that treatment duration can be adjusted as necessary to achieve the optimum dialysis dose.
References


