RENAL CARE

CITRASATE™

HIGH-FLUX HEMODIALYSIS AND ONLINE HEMODIAFILTRATON WITH CITRASATE

NIPRO MEDICAL EUROPE

Index

What is Citrasate™?

Citrasate is an innovative formula of acid concentrate for dialysis that contains 0.8 mmol of citric acid and 0.3 mmol/l of acetate, instead of the traditional 3 mmol/l of acetate contained in standard acid concentrates.

The use of an acidifying agent in acid concentrates for dialysis is necessary in order to reach a neutral pH well tolerated by the body and to prevent the precipitation of calcium and magnesium carbonate.

What are the side effects of acetate in dialysis and what are the benefits offered by Citrasate?

With the introduction of the bicarbonate dialysis, the concentration of acetate (or acetic acid) was reduced to 3 mmol/l. However, during the dialysis treatment, acetate ions can cause a series of undesired physiological side effects because of their metabolism to carbon dioxide under consumption of oxygen. The possible side effects of acetate during dialysis are summarized in Table 1.

Physiological effects of acetate during its metabolism	Possible symptoms during and after treatment
Vasodilatation	Hypotension Arrhythmia
Increased need of O_2	Hypoxemia
Unphysiological formation of intermediate products of metabolism (e.g. aldehydes)	Headache Nausea
Cytokine induction (IL-1) in monocytes	Stimulation of long-term side effects of dialysis treatment (e.g. atherosclerosis and microinflammation)

Table 1: Possible side effects of acetate in dialysis [1-3]

The innovative acid concentrate, Citrasate, is partly acidified with citric acid, which generates citrate ions. Citrate ions possess anticoagulant properties because of their complex formation with calcium and magnesium ions. The extent of this anticoagulation is dependent on the concentration of citrate.

To achieve an effective dialysis treatment, it is necessary to prevent blood coagulation in the extracorporeal circuit by using anticoagulation, for which unfractionated heparin is generally administered.

The repeated use of heparin, however, can cause several undesirable side effects. Therefore, if possible, the heparin dose used should be minimized. In the critical case of heparin-induced thrombocytopenia (HIT II), heparin must be avoided entirely. The possible side effects of unfractionated heparin are summarized in Table 2.

Possible side effects of unfractionated heparin
Increased risk of bleeding
Partial blockage of the lipid metabolism
Osteoporosis
Pruritus
Heparin-induced release of myeloperoxidase (MPO) from atherosclerotic vessels
Heparin-induced thrombocytopenia (HIT II)

Table 2: Possible side effects of unfractionated heparin in dialysis (4-8)

Because the concentration of citrate is very small Citrasate dialysate, if it is used for high-flux hemodialysis (HD), it is not necessary to evaluate the concentration of free calcium ions in the blood or to administer calcium to the blood behind the dialyzer. For the metabolism of citrate through the organism, oxygen is not necessary. In comparison to acetate, citrates half-life is much shorter.

Possible indications for dialysis with Citrasate

On the basis of experience and clinical studies, Citrasate is suited for the following patients while performing different treatment modes of blood purification:

- Pre- or post-operative patients
- Patients with cholesterol embolism
- Patients with gastrointestinal lesions
- Patients with hemorrhagic retinopathies because of diabetes
- Patients with heparin-induced side effects (e.g. pruritus or osteoporosis)
- Patients with acetate-induced side effects

What is the mechanism of Citrasate inside the dialyzer?

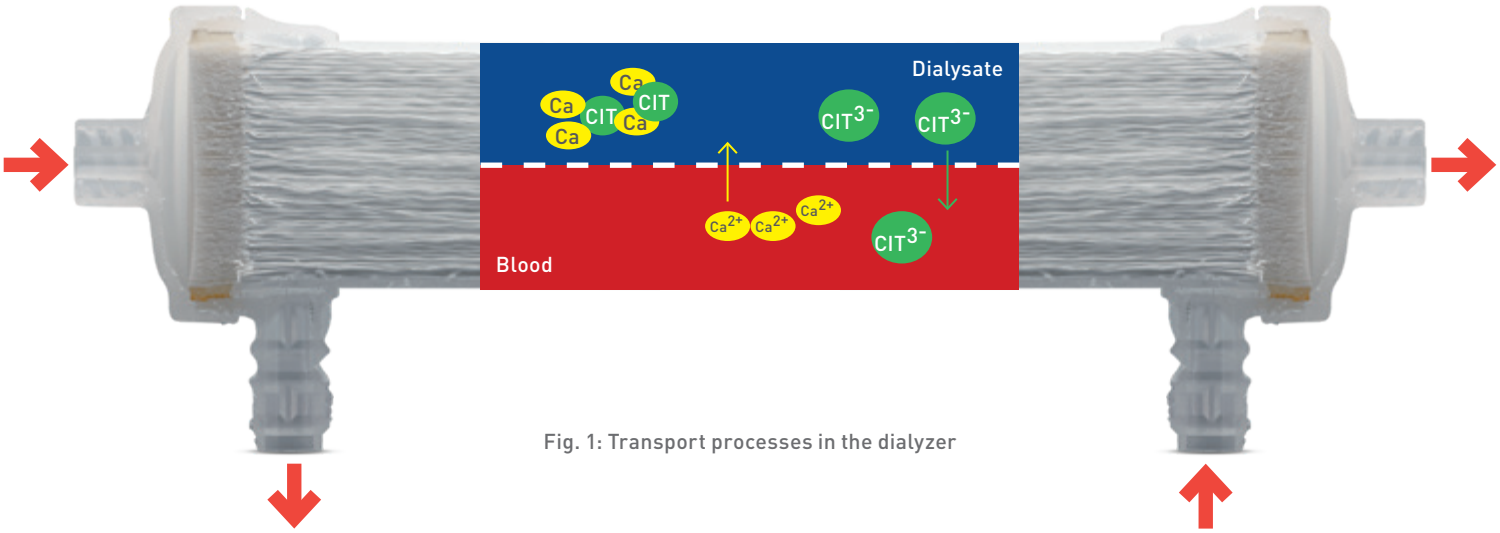


Fig. 1: Transport processes in the dialyzer

STEP 1

In his packaging and at pH 1.9 of citrasate, calcium and citrate ions do not form a complex. The formation of the calcium-citrate (Ca-citrate) complex takes place during the mixing of acid and bicarbonate components inside the dialysis machine, producing the final dialysis fluid.

- Because of the concentration gradients in the dialyzer, free citrate ions diffuse into the blood and bind free calcium ions to form a Ca-citrate complex.
- At the same time, free calcium ions diffuse from the blood to the dialysate side because the ionized calcium has been reduced due to the Ca-citrate complex formation.

Both transport processes lead to a reduction in the concentration of free calcium ions in the blood that is located in the dialyzer therefore cause a local anticoagulatory effect inside the dialyzer.

STEP 2

The Ca-citrate complex entering the blood circuit dissociates into free Ca^{2+} and citrate ions, resulting in free calcium ions again becoming available in the blood in the dialyzer. The citrate ions are metabolized to bicarbonate in the Krebs-cycle. as the dosage of citrate is very low in comparison to regional citrate anticoagulation and the muscle cells can also metabolize citrate can be metabolized by muscle cells, Citrasate can also be used for patients with liver insufficiency.

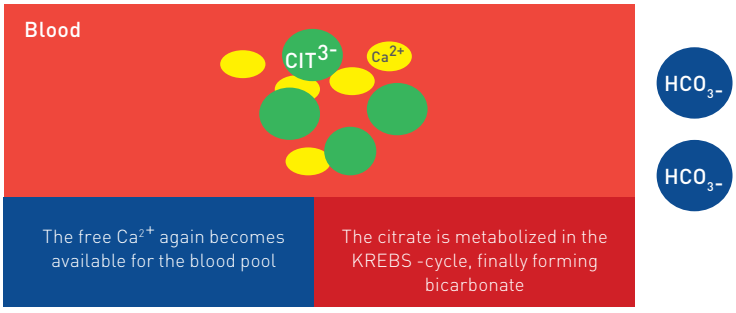


Fig. 2: Removal of calcium-citrate-complex in the blood and organism

Clinical studies with Citrasate

High-flux hemodialysis (HD)

Reduction in heparin dose which was associated with shorter bleeding time

Kossmann et al. (9) switched 31 patients from normal dialysate containing acetate (NCD) to Citrasate and gradually reduced the heparin dosage. Even with the reduction of heparin by 55%, all the treatments with Citrasate successfully completed without clotting problems.

PATIENTS AND METHODS

31 chronic patients were identified as having post-dialysis bleeding times >15 minutes.

Months 1-2: standard heparin dose

Months 3-4: heparin dose lowered by 33%

Months 5-6: heparin dose lowered by another 33%

Thus, heparin dose was reduced by 55% from their initial dose.

There was no other change in treatment parameters (e.g. session duration, blood flow, dialysate flow, choice of dialyzer).

The bleeding time was measured and the dialysis dose was registered as Kt/V (urea).

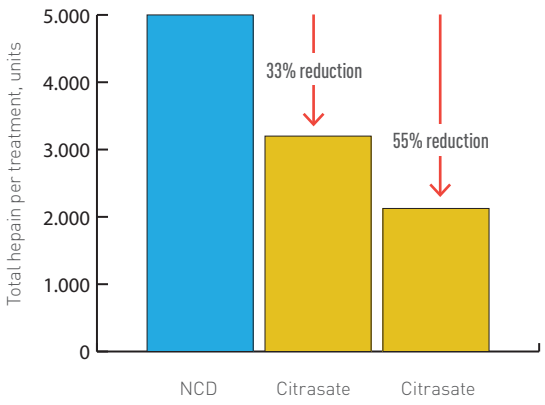


Fig. 3: Heparin dose

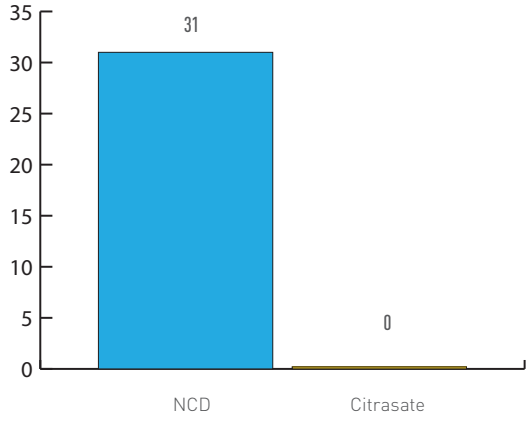
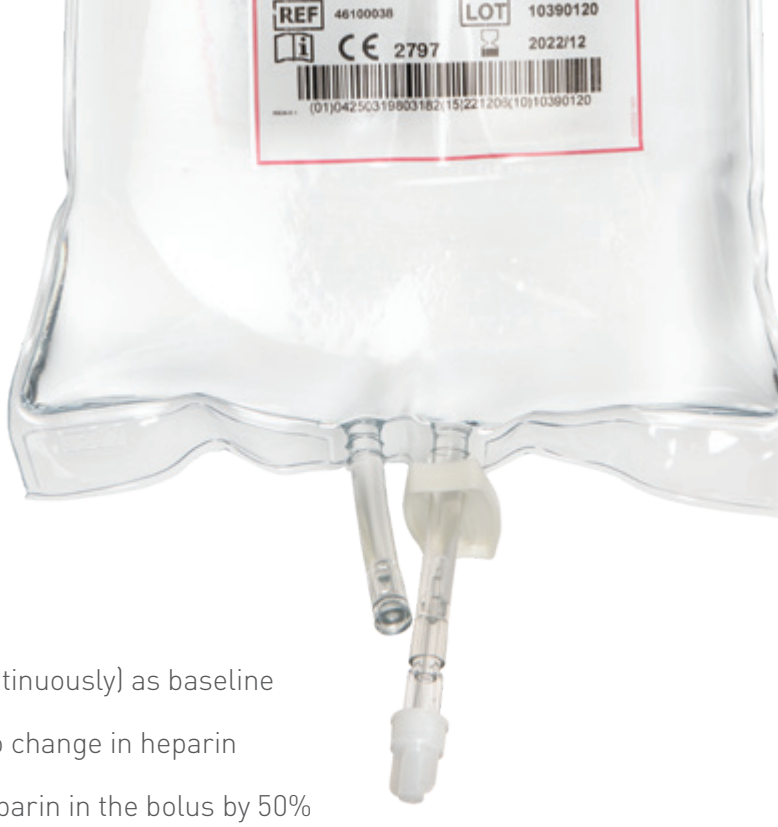


Fig. 4: Patients with bleeding times >15 min

Reduction in heparin dose

Ahrenholz and Winkler[10] switched 7 patients from a standard dialysis fluid containing acetate to Citrasate and gradually reduced the heparin dose. Despite the heparin reduction by 50%, all the treatments with Citrasate were successfully finished without clotting problems.



PATIENTS AND METHODS

7 patients treated with a high-flux dialyzer

Weeks 1-2: standard dialysate and heparin (bolus + continuously) as baseline

Weeks 3-6: changed standard dialysate to Citrasate; no change in heparin

Weeks 7-10: dialysis with Citrasate and reduction of heparin in the bolus by 50%

Weeks 11-14: dialysis with Citrasate, bolus of heparin remains at 50%, and reduction of heparin in the continuous dosage by 50%, resulting in a total reduction of 50%

There was no other change in treatment parameters (e.g. session duration, blood flow, dialysate flow, choice of dialyzer).

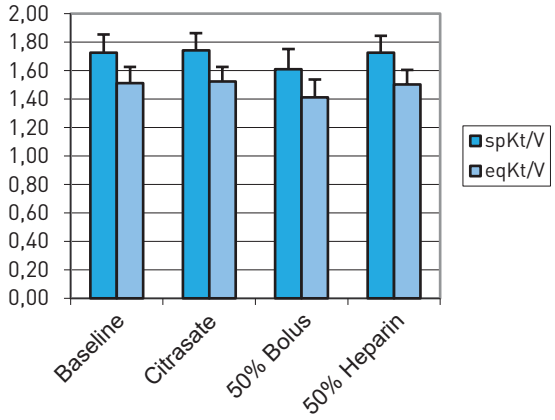


Fig. 5: Dialysis dose
spKt/V und eqKt/V; n=7

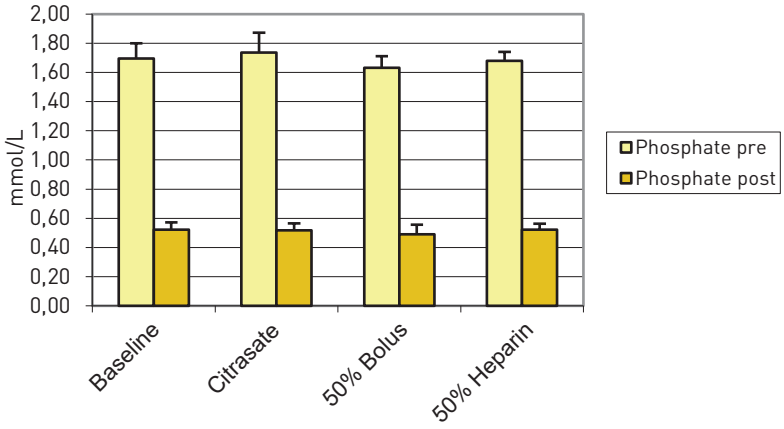


Fig. 6: Phosphate removal
Phosphate pre and post HD; n=7

The results in Fig. 5 show that no significant drop in the dialysis dose or in other clearance values (e.g. phosphate in Fig. 6) takes place despite the reduction of heparin by 50%. In the switch from dialysis fluid containing acetate to Citrasate, without a change in heparin dosage, no increase of dialysis dose (spKt/V) was found in comparison to Kossmann et al.[11]

Recently, Sands et al.[26] confirmed the possibility of a heparin reduction between 20-30% in a prospective multi-center trial. In 92% of 277 dialysis patients, it was found that the dialysis treatment could finish without significant change of urea clearance or adverse events, such as clotting or bleeding.

Increase in dialysis dose and removal of Beta-2 Microglobulin

Kossmann et al.[11] switched 142 patients from standard dialysis fluid containing acetate (NCD) to Citrasate and measured the dialysis dose and pre-dialytic Beta-2 Microglobulin (β2M) concentration in the plasma every month, over a period of 6 months.

A significant increase of Kt/V (Fig. 7) and reduction of pre-dialytic β2M plasma levels were observed (Fig. 8).

PATIENTS AND METHODS

142 patients were observed for 6 months

- Follow-up of pre-dialytic β2M values
- Monthly follow-up of Kt/V values

There was no other change in treatment parameters (e.g. session duration, blood flow, dialysate flow, choice of dialyzer).

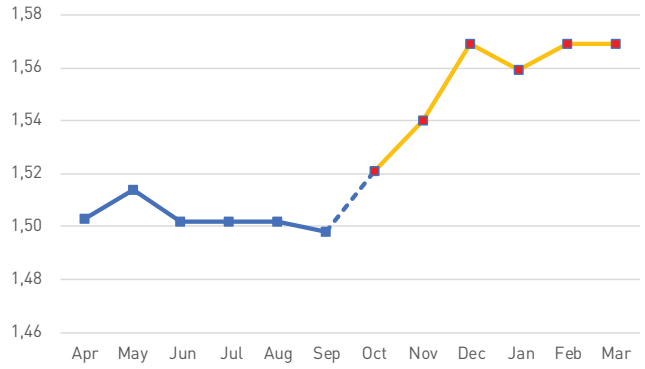


Fig. 7: Increase in Kt/V

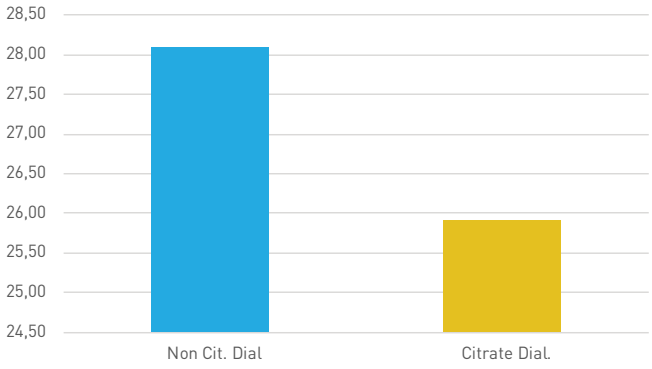


Fig. 8: Reduction in pre-dialytic plasma level of β-2 Microglobulin

Dialysis dose and calcium-bicarbonate concentration in plasma

Svara et al.[12] switched five patients from standard dialysis fluid containing acetate (AA) to Citrasate (CA) and measured the urea reduction rate and free calcium, total calcium, and bicarbonate in the plasma at the end of every treatment. A significant increase of 7% in spKt/V was observed (Fig. 9), whereas the other parameters did not change significantly (Fig. 10).

PATIENTS AND METHODS

5 patients observed for 4 weeks

- Calculation of spKt/V values
- Measurement of the pre-dialytic Ca2+, total Ca, and bicarbonate concentration in the plasma

There was no other change in treatment parameters (e.g. session duration, blood flow, dialysate flow, choice of dialyzer).

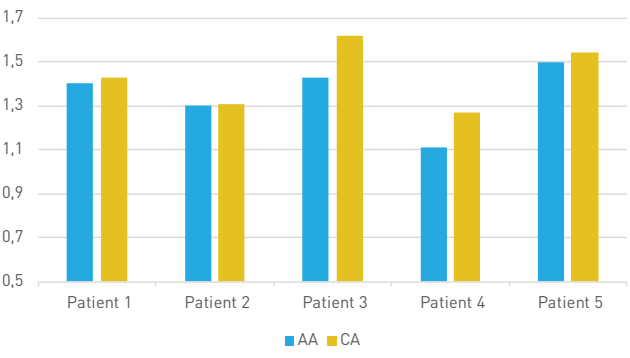


Fig. 9: Increase in spKt/V

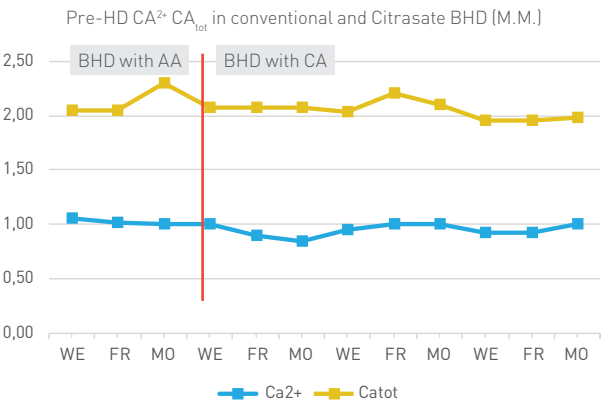
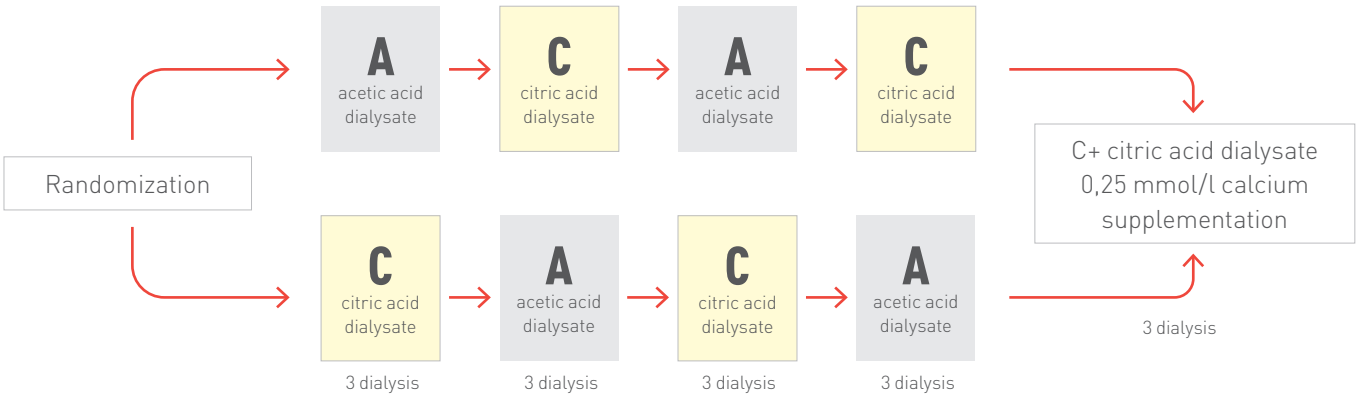


Fig. 10: Timeline of Ca2+ and total Ca in the plasma of one patient

Improvement in hemodynamic stability

From Gabutti et al.,[13] 25 patients were investigated. Each underwent a total of 375 dialysis sessions either with a standard acetate dialysate (A), a citrate-containing dialysate with (C+), and a citrate-containing



dialysate without (C) calcium supplementation (0.25 mmol/l) adhering to the following study design:

In hypertensive patients, the citrate dialysis resulted in a significantly lower systolic blood pressure (Fig. 11) and an increase in stroke volume (Fig. 12).

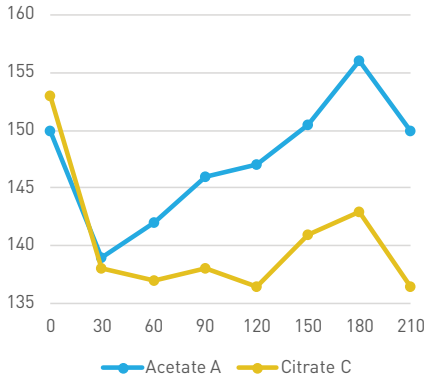


Fig. 11: Systolic blood pressure

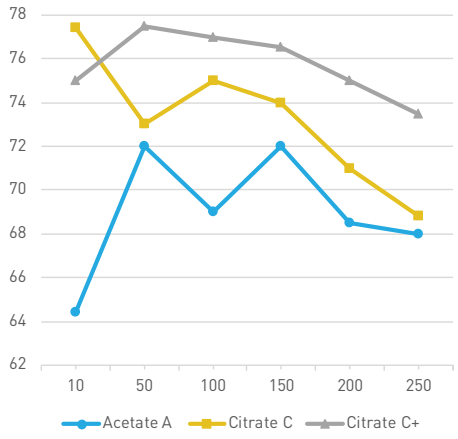


Fig. 12: Stroke volume

Reduction in thrombus formation in the dialyzer using citrate

Citrate versus heparin after 4 hours of hemodialysis

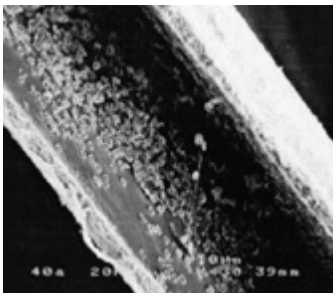


Fig. 13: Polysulfone membrane with low molecular weight heparin[14]

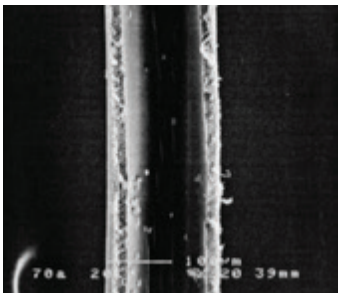


Fig. 14: Polysulfone membrane with regional citrate anticoagulation[14]

Fig. 15: Dialyzer after rinse back, following 4 hours of hemodialysis with dialysate containing acetate[15]

Fig. 16: Dialyzer after rinse back, following 4 hours of hemodialysis with Citrasate[15]

Positive impact of Citrasate on coagulation parameters

Since a very low concentration of citrate is contained in Citrasate, its anticoagulatory effect can only develop in the dialyzer during dialysis (i.e. no systemic anticoagulation is to be expected).

Gabutti et al.[13] measured no significant changes in the formation of the TAT-complex and the F1 and F2 prothrombin fragments (pre- and post-dialytic) in 25 patients and 375 treatments when there was a switch from acetate containing dialysate to one containing citrate. Leimbach et al.[16] made the same observation for the pre- and post-dialytic activated clotting time (ACT) values in 7 patients. Ahrenholz et al.[10] confirmed these findings. In this context, they were also able to show that the ACT dropped even if heparin was

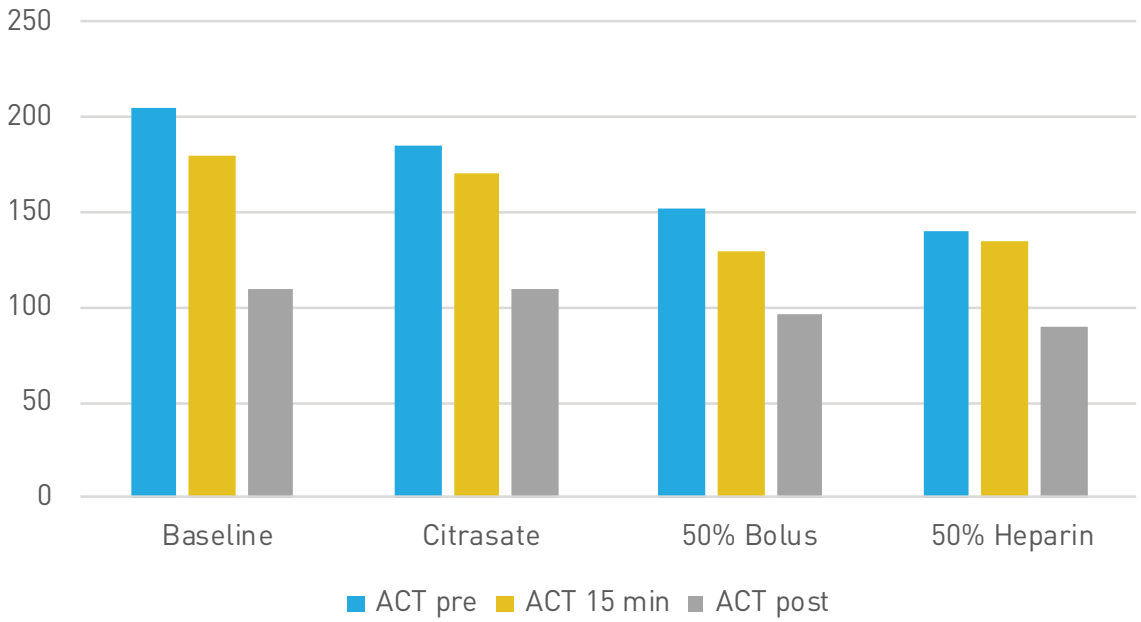


Fig. 17. Time dependence of activated clotting time (ACT) as a function of heparin reduction during dialysis treatment with acetate dialysate versus Citrasate

reduced by 50%, and no clotting events occurred in the dialyzer and in the extracorporeal circuit.

Positive influence of Citrasate on biocompatibility

Myeloperoxidase (MPO) is considered a marker of oxidative stress and a parameter of inflammation in patients[6] suffering from kidney disease or for patients to be treated with extracorporeal blood purification.[17]

MPO can induce vascular complications with several different mechanisms:

- Inhibition of NO-dependent vasorelaxation
- Production of endogenous NO-inhibitors
- Oxidation of LDL with consecutive increased reception in local macrophages
- Production of reactive species

The plasma levels of MPO are associated with atherosclerotic complications and mortality of patients with acute renal failure.[17]

Heparin was shown to stimulate the release of MPO from atherosclerotic vessels and to stimulate the activation of leucocytes,[18] independently of any stimulation by the dialyzer.[19] Using unfractionated or low

molecular weight heparin for anticoagulation, MPO and platelet factor 4 will be released immediately after starting dialysis treatment.[20] However, using citrate for regional anticoagulation, the release of MPO could be inhibited entirely.[20] By means of regional citrate anticoagulation for critical ill acute patients, a significant decrease of mortality was observed[21] using central veno-venous hemodialysis (CVVH) as the treatment mode. A better recovery of kidney function is supposed as reason.

Ahrenholz and Winkler[10] examined the MPO plasma levels and the leucocyte numbers pre-and post-dialytic, as well as 15 minutes after the beginning of the dialysis session, in accordance to the following study protocol:

PATIENTS AND METHODS

8 patients were treated with high-flux dialysis

Weeks 1-2: standard dialysate and previous amount of heparin (bolus + continuously) as baseline treatment

Weeks 3-6: changed standard dialysate to Citrasate; no change in heparin

Weeks 7-10: dialysis with Citrasate and reduction of heparin in the bolus by 50%

Weeks 11-14: dialysis with Citrasate, bolus of heparin remains at 50%, and reduction of heparin in the continuous dosage by 50%, resulting in a total reduction of 50%

There was no other change in treatment parameters (e.g. session duration, blood flow, dialysate flow, choice of dialyzer).

Fig. 18 shows that no significant changes in leucocyte numbers were observed regardless of the amount of dialysate or heparin used. 15 minutes after the start of the dialysis session, however, a significantly lower induction of MPO plasma levels could be observed between acetate-containing dialysate and Citrasate dialysate with the reduced amount of heparin (Fig. 19).

These results can be considered as the first proof that dialysis with Citrasate appears to be more biocompatible for chronic dialysis patients because the reduction of acetate and heparin concentration in dialysate diminishes the inflammatory and oxidative potential in the blood. The question whether the mortality of chronic dialysis patients can be reduced by Citrasate dialysis remains reserved for long-term investigations with a larger patient population.

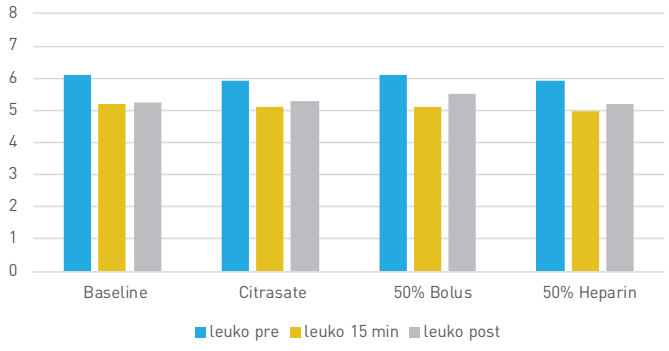


Fig. 18. Leucocyte number during dialysis with acetate-containing dialysate or Citrasate

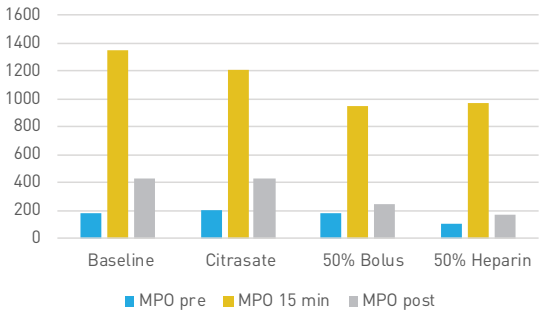


Fig. 19. Change of MPO-plasma levels during dialysis with acetate-containing dialysate

The successful application of Citrasate for the heparin-free "slow efficiency" dialysis (SLED) for acute treatment of critically ill patients with multiorgan failure or advanced liver failure was described by Ahmad and Tu.[24]


Canister
Citrasate
Acid Concentrate
for Bicarbonate Dialysis
460
45x
5L
K 2,00 Ca 1,50 Gluc 1,00
1l 460 + 42.225 l H2O ISO 23500-3
+ 1.775 l NaHCO3 8,4%
1l 460
Natrii chloridum 263,00 g/l
Kalii chloridum 6,71 g/l
Magnesii chloridum x 6H2O 4,57 g/l
Calcii chloridum x 2H2O 9,92 g/l
Acidum citricum 6,92 g/l
Natrii acetatis x 3H2O 1,84 g/l
Glycosum anhydricum 45,00 g/l
H2O ad 1000 ml
Conductivity (ready to use sol.) 14,01 mS/cm
Na+ 139,75 mmol/l
K+ 2,00 mmol/l
Mg2+ 0,50 mmol/l
Ca2+ 1,50 mmol/l
Citrate3- 0,80 mmol/l
CH3COO- 0,30 mmol/l
HCO3- 37,04 mmol/l
Cl- 106,00 mmol/l
Glucosum 1,00 g/l
de: Saures Konzentrat (A-Konzentrat) für die Bicarbonat- Hämodialyse (Hinweis: eine Übermischung mit Bicarbonat (B-Konzentrat) ist zu vermeiden) en: Acid concentrate (A-concentrate) for bicarbonat haemodialysis (Note: over mixing with bicarbonate concentrate (B concentrate) should be avoided) fr: le concentre de dialyse acide (concentre A) pour l'hémodialyse au bicarbonate (note : il faut éviter de trop mélanger avec le concentré de bicarbonate (concentré B). sv: Surt dialyskoncentrat (A-koncentrat) för bikarbonat-hemodialys (OBS: en överblandning med bikarbonat-koncentrat (B-koncentrat) måste undvikas). da: syreholdigt dialysekoncentrat (A-koncentrat) til bikarbonat-hæmodialyse (Bemærk: En for høj blanding med bikarbonat-koncentrat (B-koncentrat) skal undgås) no: surt dialysekonsentrat (A-konsentrat) for bikarbonat-hemodialyse (henvisning: en blanding med bikarbonat-konsentrat (B-konsentrat) må unngås) lt: Rugštinis dializes koncentratas („A" koncentratas), skirtas bikarbonato hemodializei (nurodymas: reikia vengti maišymo su bikarbonato koncentratu („B" koncentratu)). lv: Lietošanai gatava bikarbonata hemodialīzes šķiduma sastāvdaļa ir norādīts uz attiecīgas A-komponentes etiķetes.Izmanto tikai un tikai pec atšķaidīšanas ar dejonizetu udeni un piemerota skabes komponenta pievienošanas.
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17033 Neubrandenburg/ Germany
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CE 2797
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(01)04250319507431(15)999999(10)XXXXXXXXXXXXXXX


Bag
Polytainer
Citrasate®
Acid Concentrate for Bicarbonate Dialysis
461
K+ 2,00 mmol/l
Ca2+ 1,25 mmol/l
Glucose 1,00 g/l
3,8 L
REF 46100038
LOT 10390120
CE 2797
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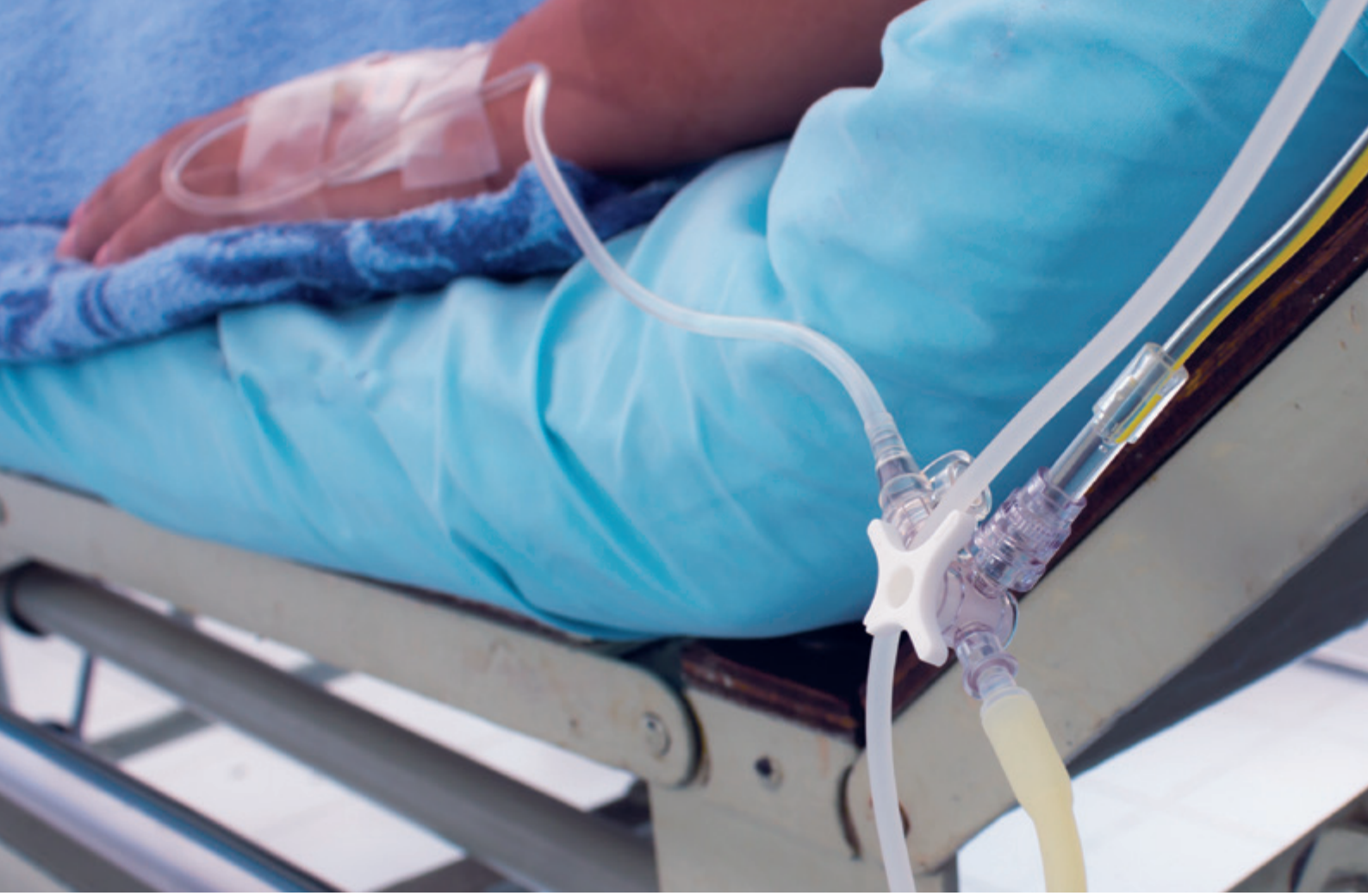
Citrasate®
460
Acid Concentrate for Bicarbonate Dialysis
4,5 L
K 2,00 Ca 1,50 Gluc 1,00



Online hemodiafiltration (HDF)

The results presented so far relate exclusively to high-flux hemodialysis with Citrasate. The following chapters relate to online hemodiafiltration in both pre- and post-dilution.

The first extensive investigation applying Citrasate in HDF was performed by Ahrenholz et al.[27] and Winkler et al.[28] with 8 patients. Since the substitution fluid for online HDF is prepared directly from the dialysate, the use of Citrasate means the infusion of a considerable amount of citrate directly into the blood will occur.

During online HDF in pre-dilution mode, the substitution fluid will be infused into the blood before the dialyzer, which means citrate will be included in the mass transfer processes of the dialyzer. During online HDF in post-dilution mode, the infusion of citrate containing fluid takes place after the dialyzer and into the peripheral blood of the patient. Since the effects of Citrasate on free calcium ion concentration and coagulation system cannot be precisely predicted, Citrasate was first applied in the pre-dilution mode of online HDF.

The level of calcium and phosphate in plasma

Because of the previous high-flux dialysis studies[10] with 1.25 mmol/l calcium in the Citrasate dialysate, the calcium concentration was increased to 1.50 mmol/l. The post-treatment values of Ca2+ level out at 1.09 mmol/l for HD and HDF pre-dilution with Citrasate, as shown in Fig. 23. The same value was also achieved for HDF pre-dilution with standard dialysate with 1.25 mmol/l Ca2+. The values for the total calcium amounts are shown in Fig. 24.

Patients usually treated with standard concentrate with 1.25 mmol/l Ca2+ should receive 1.50 mmol/l Ca2+ after changing to Citrasate. This increase becomes necessary to compensate for the iCa-losses resulting from the calcium-citrate complex formation.

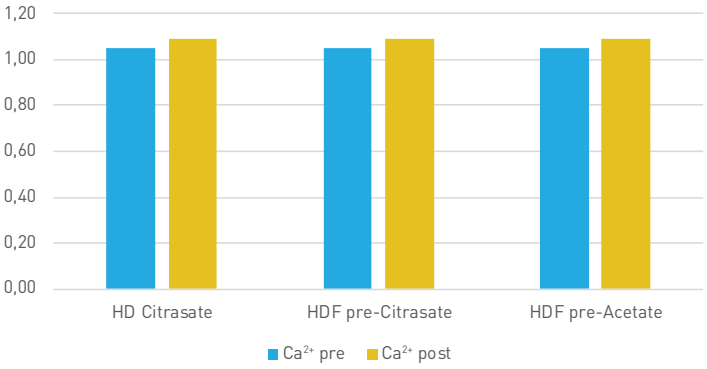


Fig. 23: Ca2+ pre and post treatment; n=8
Ca2+ concentrations pre- and post-treatment for different treatment modes with and without Citrasate

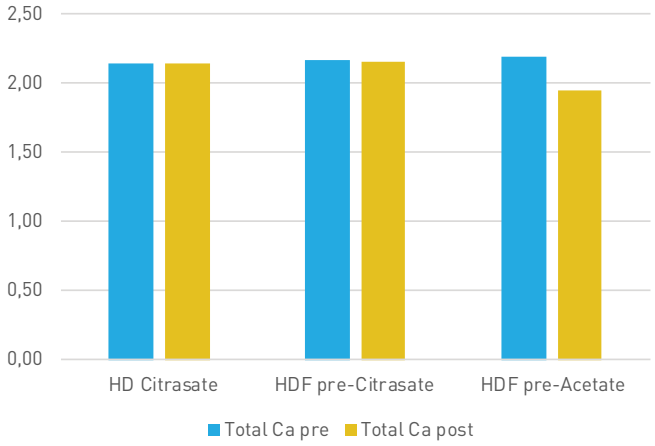


Fig. 24: Total Ca pre- and post-treatment; n=8
Total Ca concentrations pre- and post-treatment for different treatment modes with and without Citrasate

The balance between changes of total Ca and ionized Ca (iCa) during treatments can be expressed as the Ca-GAP, according to the following equation from Gabutti el al. (13, 29):

Ca-GAP = (totalCa post – totalCa pre) – (iCa post – iCa pre)

If the metabolization of citrate is quick, the Ca-GAP becomes smaller than 0,2 (13, 29). As the results in Fig. 25 show, on average this condition was fulfilled.

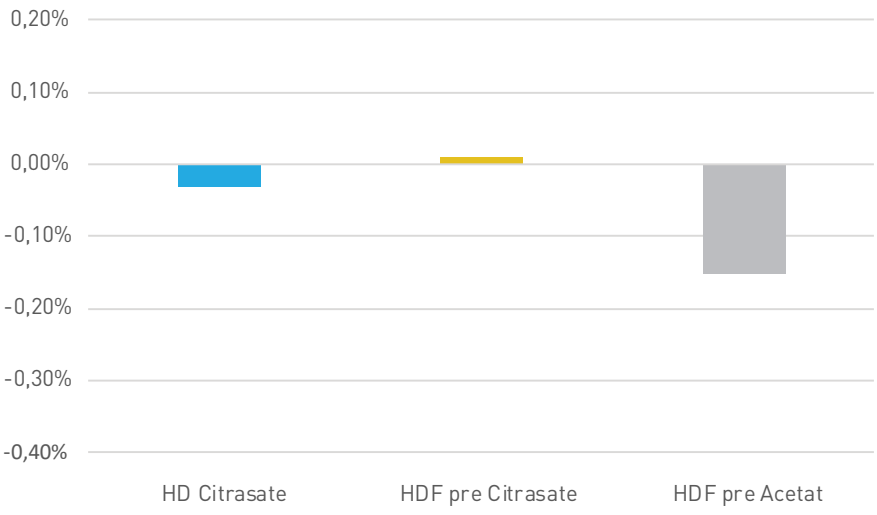


Fig. 25: Ca-GAP; n=8
Ca-GAP for different treatment modes with and without Citrasate

The calcium-phosphate balance is determined largely by the parathyroid hormone (PTH). Disruptions in this balance due to non-physiological treatment conditions would, therefore, be reflected in the concentrations of Ca2+, phosphate, and PTH.

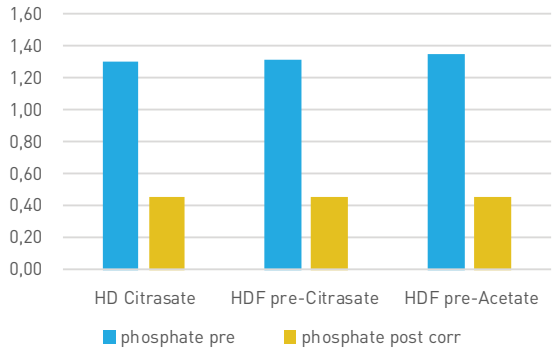


Fig. 26: Phosphate pre- and post-treatment; n=8
Pre- and post-treatment concentrations of phosphate with different treatment modes

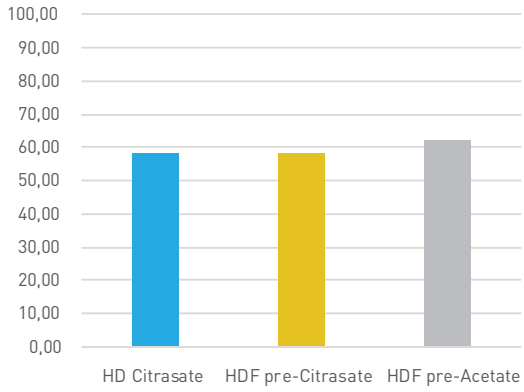


Fig. 27: iPTH pre-treatment; n=8
Pre-treatment concentration of intact parathyroid hormone (iPTH) with different treatment modes

As shown in Figures 26 and 27, however, no significant differences between online HDF post-treatment values with Citrasate and standard concentrate were observed.

Kron et al.[23] successfully performed a heparin-free online hemodiafiltration in pre-dilution mode with patients at risk of bleeding and HIT II using calcium-free Citrasate as dialysis fluid and substitution solution. 32 treatments were performed without clotting problems. To maintain a constant concentration of calcium ions in the plasma, it was necessary to infuse calcium chloride into the venous line.

Online hemodiafiltration in post-dilution mode

Following previous studies on the suitability of Citrasate concentrate for high-flux hemodialysis (HD) and online hemodiafiltration (HDF) in pre-dilution mode, it should now be investigated whether the use of citrate-containing dialysate can present issues during online HDF in post-dilution mode. In contrast to HDF pre-dilution, the infusion of citrate-containing solution with online HDF post-dilution occurs after the dialyzer (i.e. directly into the peripheral blood of the patient), so the physiological effects are more difficult to assess.

As with online HDF pre-dilution, the following questions were posed: Is it possible for online HDF post-dilution ...

- ...to maintain the reduced heparin amount of 50%?
- ...to improve the dialysis efficacy?
- ...to reduce the activation of MPO?
- ...to keep plasma concentrations of calcium and phosphate in the physiological optimal range?

Seven out of the eight patients from the online HDF pre-dilution study continued with the post-dilution investigation, as one patient dropped out. The heparin dosage was reduced between 30-50% compared to the baseline in studies involving high-flux dialysis and acetate-containing standard concentrate.

The following treatment parameters were used:

- Dialyzer surface area: 2,2 m^2
- Blood flow: 300 ml/min
- Dialysate flow: 500 ml/min
- Substitution rate for post-dilution: 60 ml/min.

THE RESULTS ARE SUMMARIZED IN THE SECTIONS THAT FOLLOW...

Reduction in heparin dose

In principle, Citrasate can be used for online HDF in post-dilution with a reduced amount of heparin (up to 50%) compared to standard dialysate.

Fig. 28 compares the activated prothrombin times (aPTT) in four different treatment modes using either Citrasate or standard concentrate. There is clearly no influence of Citrasate on the activation of systemic coagulation.

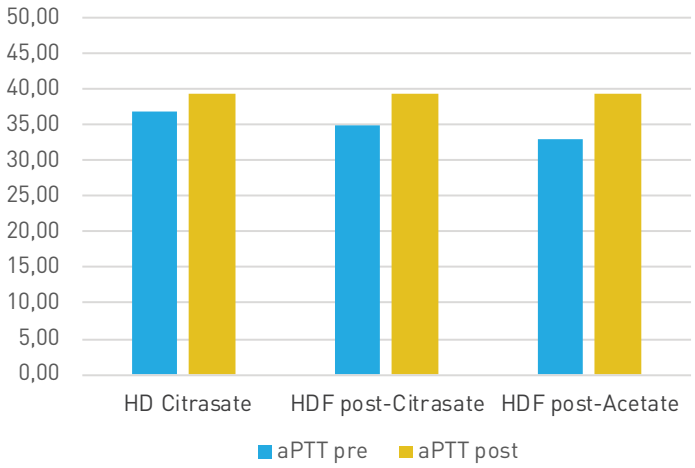


Fig. 28: aPTT pre- and post-treatment; n=7
Activated prothrombin times pre- and post-treatment with different treatment modes

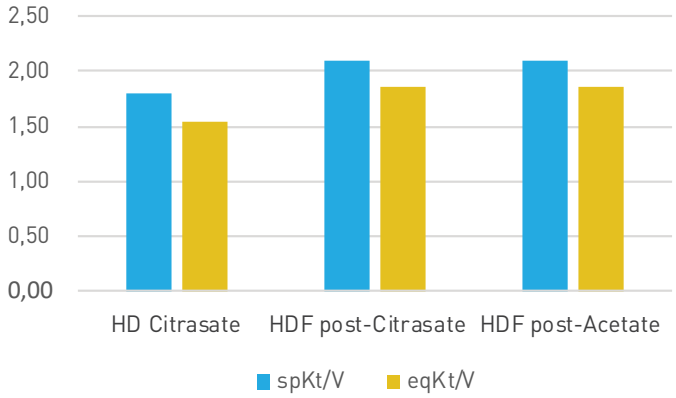


Fig. 29: spKt/V and eqKt/V; n=7
Single pool and equilibrated Kt/V- values for different treatment modes

Increase in dialysis efficacy and β2 Microglobulin removal

Online HDF post-dilution proved to be more effective than high-flux HD and online HDF pre-dilution in the removal of low molecular weight molecules (e.g. urea).

However, a difference in effectiveness between online HDF post-treatment with Citrasate and standard concentrate could not be detected (see Fig. 29).

Regarding the removal of β2 Microglobulin, an improvement in effectiveness compared to high-flux HD could be seen, but a difference between online HDF post-dilution with Citrasate and standard concentrate, as it was seen in the pre-dilution treatments, could not be determined.

The level of calcium and phosphate in plasma

As seen during the HDF pre-dilution treatments, the concentration of calcium was raised to 1.50 mmol/l for the online HDF post-dilution treatments.

Fig. 31 shows the Ca2+ concentrations level out to values of about 1.10 mmol/l after treatment, as seen with online HDF treatments using standard dialysate (Ca2+ = 1.25 mmol/l). Losses of ionized calcium by chelation were adequately compensated by choosing a higher dialysate Ca2+ for online HDF in both pre- and post-dilution. Fig. 32 demonstrates that the total calcium amount is reduced more significantly in online HDF post-dilution with standard concentrate than the same treatment with Citrasate.

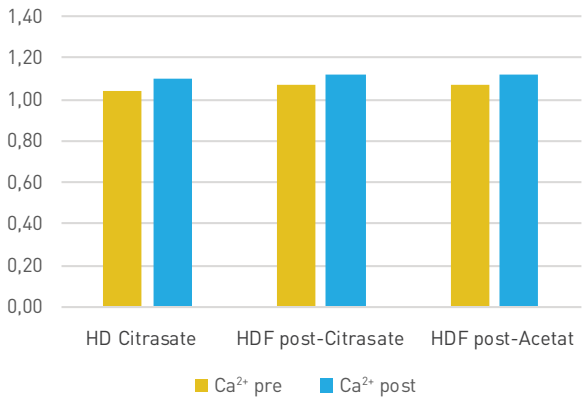


Fig. 31: Ca^{2+} pre- and post-treatment; n=7
Mean values of Ca^{2+} pre- and post-treatment for different treatment modes with and without Citrasate

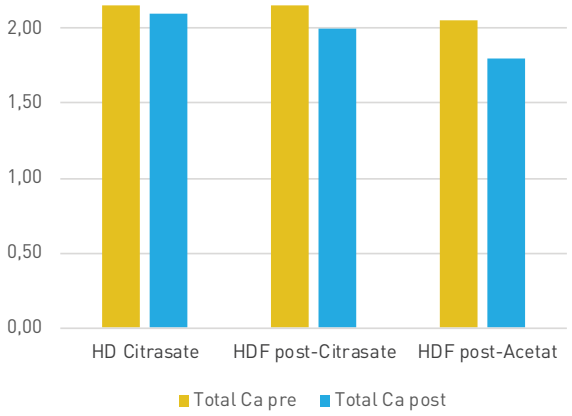


Fig. 32: Total Ca pre- and post-treament; n=7
Mean values of total Calcium pre- and post-treatment with different treatment modes with and without Citrasate

This can be explained by the metabolization of citrate during treatment, where chelated calcium will be released into the blood. As already described in the section on online HDF pre-dilution, changes in the balance between ionized and total calcium can be described by the Ca-GAP, which should be less than 0.2 (13, 29).

Fig. 33 shows that online HDF post-dilution with Citrasate gives better results than with standard concentrate for total Ca-GAP.

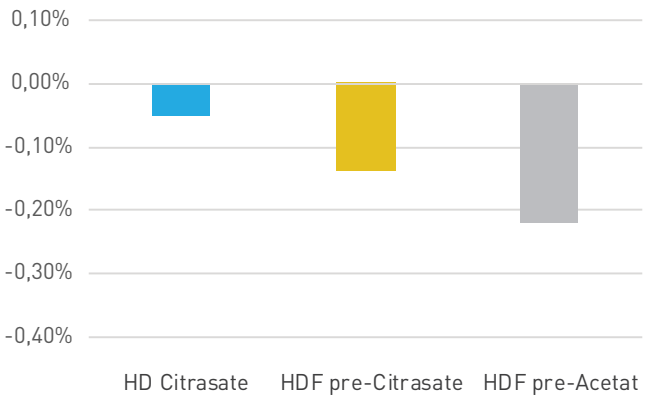


Fig. 33: Total Ca-GAP; n=7
Ca-GAP for different treatment modes

Accordingly, no surplus amount of bound Ca remains in the bloodstream, which would indicate an incomplete metabolism of the calcium citrate. According to studies by E. Bauer et al.[29], this is also not to be expected. In this study, citrate kinetics during citrate anticoagulation were investigated both in patients with normal renal function and those undergoing hemodialysis. It was found that citrate is also metabolized adequately with renal failure, as well as with mild hepatic dysfunction. Only in patients with severe liver failure is citrate anticoagulation not indicated. If one considers that, with citrate anticoagulation, the citrate infusion rate is about 0.3 mmol/kg/h, while with online HDF in post-dilution with Citrasate dialysate, it is only about 0.04 mmol/kg/h, then problems arising from incomplete citrate metabolism are not to be expected.

As shown in Figures 34 and 35, however, no significant differences between online HDF post-dilution treatment values with Citrasate and standard concentrate were observed.

Regarding other parameters measured, such as bicarbonate (HCO_3^-), Na^+, K^+, there were no significant differences in the individual study phases.

The mean EPO dose (Aranesp®) and iron intake (Ferrlecit) remained constant during all study phases.

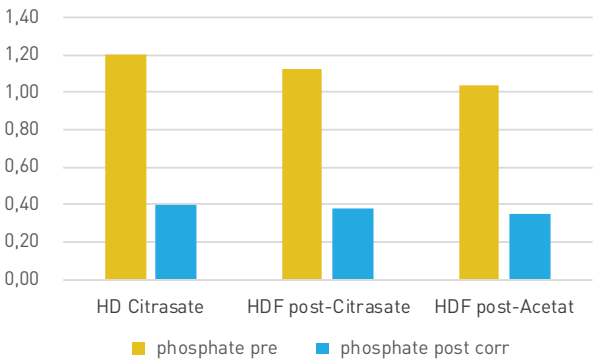


Fig. 34: Phosphat pre- and post-treatment; n=7
Plasma phosphate concentrations pre- and post-treatment for different treatment modes with Citrasate and standard concentrate

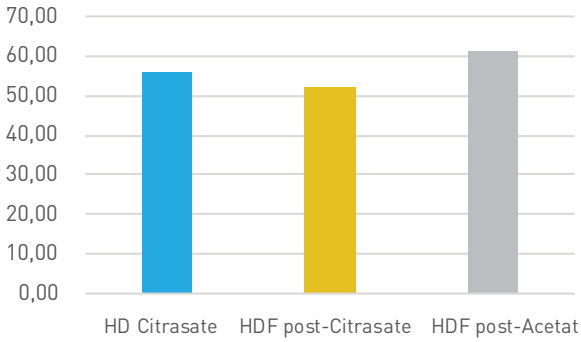


Fig. 35: iPTH pre-treatment; n=7
Pre-treatment concentration of intact parathyroid hormone (iPTH) for different treatment modes with Citrasate and standard concentrate

Citrasate can be used on every standard dialysis machine

MACHINES AND METHODS

Polakovic et al.[25] carried out double measurements with A-concentrate with acetic acid (AA) or citric acid with seven types of dialysis machines from four manufacturers: Dialog by B.Braun, 4008/5008 by Fresenius, AK 100/200/200S by Gambro, and DBB05 by Nikkiso and Surdial X by Nipro.

All machines were preset for conventional acetate-containing A-concentrates.

- Concentrations of Na^+-, K^+-, Ca^{2+} in final dialysate were measured by ion selective electrodes. The bicarbonate concentration was calculated from measured pH and pCO_2 values.
- Measurements were performed for four different combinations of sodium and bicarbonate set values covering the whole range of commonly used settings (132/28, 132/39, 148/28, and 148/39 mmo/l).

Results of the *in vitro* measurements[25]

1. The performance of all tested dialysis machine types was problem-free and without any alarms.
2. The control of Na+ und HCO3- concentration worked with the entire concentration range for all machines tested.
3. The concentration of ionized calcium was found to be 0.35-0.55 mmol/l lower in the citrate-containing dialysate.
4. The bicarbonate concentration exhibited a tendency towards slightly higher values (0.5-2.5 mmol/l) when using Citrasate concentrate compared to standard dialysate, depending on the type of mixing system (volumetric or conductivity) of the dialysis machine.

Advantages of using Citrasate

The following applies to treatments in high-flux HD and online HDF in either pre- or post-dilution:

- The use of Citrasate allows for the reduction of heparin by up to 50% without the increased risk of clotting issues in the extracorporeal circuit or dialyzer, and without a reduction of dialysis dose prescribe
- The use of Citrasate keeps plasma concentrations of calcium and phosphate in a physiologically optimal range
- The use of Citrasate can reduce long bleeding times for patients with high risk of bleeding
- The use of Citrasate increases the hemodynamic stability of hypertensive patients during high-flux HD treatment
- The use of Citrasate was proven to be more biocompatible for chronic dialysis patients by decreasing inflammatory and oxidative stress
- The successful application of Citrasate works on every standard dialysis machine
- The level of ionized Ca with Citrasate corresponds to that of standard dialysate with 1.25 mmol/l Ca^{2+} after an increase of dialysate calcium from 1.25 to 1.50 mmol/l
- The use of Citrasate offers an economical benefit by helping hospitals save on heparin

Comparison of the composition of ready-to-use citric acid dialysis solution *versus* acetic acid

The electrolyte concentrations shown below are related to ready-to-use dialysis solutions in dilution/the following dilution ratio?:

1 L of Dxxx + 1,225 L of bicarbonate concentrate + 32,775 L of purified water

1 liter bicarbonate concentrate contains 84.0 g $NaHCO_3$

Type		Na+	K+	Ca++	Mg++	Cl-	Citrate-	Acetate-	HCO_3-	Glucose anh.
		mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	g/l
Citrasate	416	135.30	1.00	1.25	0.50	104.50	0.80	0.30	32.60	1.00
Acetate	259	138.00	1.00	1.25	0.50	107.50		3.00	32.00	1.00
Citrasate	417	135.30	1.00	1.50	0.50	105.00	0.80	0.30	32.60	1.00
Acetate	296	138.00	1.00	1.50	0.50	108.00		3.00	32.00	1.00
Citrasate	410	135.30	2.00	1.25	0.50	105.50	0.80	0.30	32.60	1.00
Acetate	761	138.00	2.00	1.25	0.50	108.50		3.00	32.00	1.00
Citrasate	411	135.30	2.00	1.50	0.50	106.00	0.80	0.30	32.60	1.00
Acetate	293	138.00	2.00	1.50	0.50	109.00		3.00	32.00	1.00
Citrasate	412	135.30	3.00	1.25	0.50	106.50	0.80	0.30	32.60	1.00
Acetate	283	138.00	3.00	1.25	0.50	109.50		3.00	32.00	1.00
Citrasate	413	135.30	3.00	1.50	0.50	107.00	0.80	0.30	32.60	1.00
Acetate	257	138.00	3.00	1.50	0.50	110.00		3.00	32.00	1.00
Citrasate	414	135.30	4.00	1.25	0.50	107.50	0.80	0.30	32.60	1.00
Acetate	263	138.00	4.00	1.25	0.50	110.50		3.00	32.00	1.00
Citrasate	415	135.30	4.00	1.50	0.50	108.00	0.80	0.30	32.60	1.00
Acetate	787	138.00	4.00	1.50	0.50	111.00		3.00	32.00	1.00

Type D 200 dilution	Na^+mmol/l	HCO_3^- mmol/l
1+1.225+32.775	35	35

The electrolyte concentrations shown below are related to the ready-to-use dialysis solution in dilution 1:45:

1 L of Dxxx + 1,775 L of bicarbonate concentrate + 42,225 L of purified water

1 liter bicarbonate concentrate contains 84.0 g $NaHCO_3$

Type		Na+	K+	Ca++	Mg++	Cl-	Citrate-	Acetate-	HCO3-	Glucose anh.
		mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	mmol/l	g/l
Citrasate	460	139.75	2.00	1.50	0.50	106.00	0.80	0.30	37.04	1.00
Acetate	871	139.00	2.00	1.50	0.50	106.00		3.00	36.00	1.00
Citrasate	463	139.75	3.00	1.50	0.50	107.00	0.80	0.30	37.04	1.00
Acetate	874	139.00	3.00	1.50	0.50	107.00		3.00	36.00	1.00

Dilution with bicarbonate concentrate	Na^+mmol/l	HCO_3^- mmol/l
1+1.775+42.225	39.44	39.44

Other compositions are available upon request. For packaging sizes, please contact your local Nipro representative.

Please contact your country representative for product availability and information.

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