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How much is catheter flow influenced by the use of closed luer lock access devices?

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Abstract

Background. To reduce infection risks in patients on hemodialysis with a long term central venous catheter, different types of closed luer lock access devices are used on the arterial and venous catheter hub. Although those connectors create a mechanically and microbiologically closed system in between two dialysis sessions, no data are available on the resistance those connectors exert on the blood flow during dialysis. Therefore, in the present study, flow resistance was determined in three different connectors.

Methods. In an in *vitro* setup, different connectors were attached in between a male (Bellco BL 307 dialysis tubing) and female luer: BD Q-Syte™ (Becton-Dickinson, Utah, USA), second edition Tego™ (ICU Medical, CA, USA), and Swan-LockÛ connector (Codan, Lensahn, Germany). For a wide range of water flow rates, pressure-flow relationships were measured, simulating catheter inflow as well as catheter outflow, by reversing the flow direction. Resistances were compared to a simple male-female connection, as in a standard bloodline-catheter connection, and mathematical corrections were performed for the use of water instead of blood.

Results. For a blood flow of 500mL/min, simulating clinical dialysis, the additional pressure drop is 118mmHg (Becton Dickinson), 52mmHg (Codan), and 23mmHg (Tego™) in the case of catheter inflow, while it is 74mmHg (Becton Dickinson), 40mmHg (Codan), and 27mmHg (Tego™) in the case of catheter outflow. Resistances are also depending on the type of tubing as used during dialysis.

Conclusions. In conclusion, the Tego™ and Codan connector show promising results for the use on a catheter hub during and in between dialysis sessions. Whether those resistances are in the safe range without the incidence of blood hemolysis will soon be investigated in an *in vivo* study.

Keywords: haemodialysis; connection; catheter; infectionflow resistance

Introduction

Ten percent of patients with a long-term central venous catheter for chronic haemodialysis develops a catheter-related blood stream infection, resulting from repeated exposure, or opening and manipulation of the catheter hub [1–4]. To reduce infection risks while handling the catheter hub, different types of closed luer lock access devices are presently available in the market. Those connectors create a mechanically and microbiologically closed system when attached to the arterial and venous catheter hub and remain in place during the dialysis treatment. Connectors are designed to ensure straight flow paths when attaching blood lines, such that blood flows up to 600 ml/min might be reached. The functional and microbiological efficacy was proven to last for up to one week and connectors are simply disinfected by swapping them [5–7].

The different connectors in the market aim to create an unobstructed fluid path in the open position, with an equivalent resistance compared with a direct connection of male and female luer. Since luer lock accesses with mechanical valves could cause haemolysis, connectors for use with dialysis blood flows are designed with a split septum of proven medical grade silicon.

Although proven to decrease and/or eliminate infection risk associated with catheter use [5–7], no data are available on the resistance those closed luer lock access devices exert on the blood flow during dialysis. Therefore, the present study set out to evaluate the flow resistance through three different closed luer lock access devices designed for application in haemodialysis and to compare them with a simple male–female connection as in a standard bloodline–catheter connection.

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Methods

Pressure–flow relationships in different catheter connectors designed for application in haemodialysis were investigated *in vitro*: BD Q-Syte™ (Becton–Dickinson, Utah, USA), second edition Tego™ (ICU Medical, CA, USA) and Swan Lock connector (Codan, Lensahn, Germany). Those luer lock connectors were attached in between a male and female luer, using a Bellco BL 307 tubing at dialysis machine side. Steady water flow, considered as a Newtonian substitute of blood, was performed by a rotary pump and measured gravimetrically as a mass variation on the balance during a pre-set time interval. Pressures up and downstream the catheter hub were measured using calibrated fluid filled pressure transducers (Becton–Dickinson Benelux, Erembodegem, Belgium).

The measurements were done for a wide range of water flow rates, simulating a catheter inflow (venous flow) as well as a catheter outflow (arterial flow) by reversing the flow direction. The measured data points were fitted using a quadratic regression analysis, as typical pressure-flow relation for an obstructed flow. Furthermore, the extra resistance as exerted exclusively by the closed luer lock access device was calculated as the difference between the pressure flow curves derived with and without the luer lock access device. Finally, since reverse osmosis (RO) water was used in the present experimental pressure-flow analysis, recalculations were performed to obtain pressure-flow relationships for blood flow. To obey dynamic similarity between pressure problems in fluids of different viscosity and density, dimensionless Reynolds numbers (Re) and Euler numbers (Eu) were kept equal in both models [8]:

$$\mathrm{Re} = \frac{\mathrm{U} \cdot \mathrm{D} \cdot \rho}{\mu} \quad \mathrm{Eu} = \frac{\mathrm{p}}{\rho \cdot \mathrm{U}^2} \qquad [1]$$

with fluid velocity U (m/s), cross sectional diameter D (m), fluid viscosity μ (Pa.s), fluid density ρ (kg/m^3) and pressure p (Pa). Since human blood at 37°C has a viscosity of 3 mPa·s and density of 1054 kg/m^3, while water at room temperature has a viscosity of 1 mPa·s and density of 998 kg/m^3, the measured water pressure and flow must be increased by a factor of 2.81 and 8.34, respectively, to obtain the corresponding pressure-flow curve for the clinical setup using blood.

In order to explain the experimental findings more in detail, the connectors were cut along the longitudinal axis to observe and make drawings of the internal geometry. Furthermore, the lumen of the connectors, as connected to different tubings with a luer lock and as currently used in dialysis, was evaluated.

Data were analysed using SigmaStat software (Jandel Scientific, San Rafael, CA, USA). Statistical analyses were carried out on the derived flow-pressure curves, using the Students *t*-test for paired samples when comparing venous and arterial flow results, and using Friedman repeated measures analysis of variance on ranks when comparing the results of the three different connectors. $P < 0.05$ was taken the limit of significant difference.

Results and discussion

The measured data points with corresponding regression lines are shown in Figure 1 for venous flow

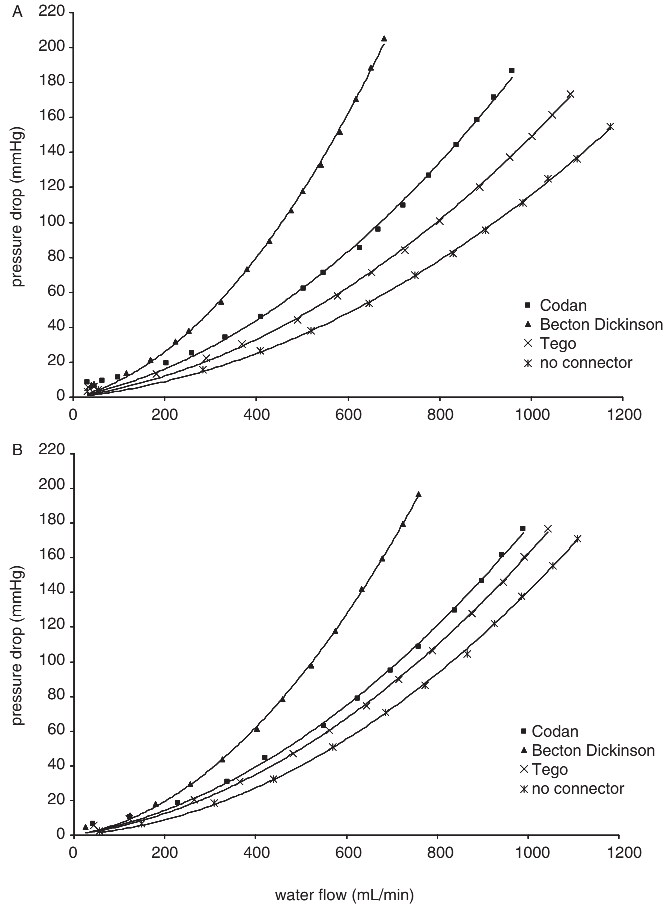

Fig. 1. Measurement results (symbols) of pressure and water flow in different types of connectors and without any connector for venous flow (catheter inflow) (Panel A) and arterial flow (catheter outflow) (Panel B).
Regression analysis for water inflow (Panel A):
Becton Dickinson: $y = 0.00035x^2 + 0.0595x$; $R^2 = 0.999$
Codan: $y = 0.00015x^2 + 0.0518x$; $R^2 = 0.997$
Tego: $y = 0.00011x^2 + 0.0383x$; $R^2 = 0.999$
No connector: $y = 0.00009x^2 + 0.0269x$; $R^2 = 0.999$
Regression analysis for water outflow (Panel B):
Becton Dickinson: $y = 0.00029x^2 + 0.0402x$; $R^2 = 0.999$
Codan: $y = 0.00013x^2 + 0.0450x$; $R^2 = 0.999$
Tego: $y = 0.00012x^2 + 0.0378x$; $R^2 = 0.999$
No connector: $y = 0.00012x^2 + 0.0199x$; $R^2 = 0.999$

(Panel A) and arterial flow (Panel B) in the case without a connector and when a Becton–Dickinson, Codan, or Tego™ connector was attached in between the male and female luers. Data points show an accurate quadratic relation ($R^2 > 0.99$) in between the water flow and pressure drop over the connection. During venous as well as arterial flow, the Becton–Dickinson connector resulted in the highest resistance, while the Tego™ connector presented the least resistance.

Figure 2 shows the pressure drop, as originated exclusively from the closed luer lock access device. This curve was calculated as the difference between the pressure flow curves derived with and without the luer lock access device and after recalculations for the use of water instead of blood in the experiments.

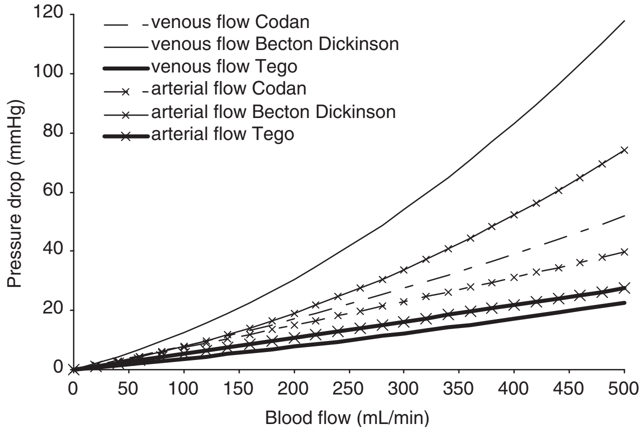

Fig. 2. Additional pressure drop as originated from a catheter connector during arterial and venous blood flow.

At a blood flow of 500 ml/min, the additional pressure drop was equal to 118 mmHg (Becton–Dickinson), 52 mmHg (Codan), and 23 mmHg (Tego^{TM}) in the case of venous flow, while it was 74 mmHg (Becton–Dickinson), 40 mmHg (Codan) and 27 mmHg (Tego^{TM}) in the case of arterial flow. Significant differences were found between the flow pressure relations for the different tested connectors for venous as well as for arterial flow (both $P < 0.001$). Furthermore, the pressure drop related to arterial flow was significantly smaller ($P < 0.001$) compared with that, during venous flow in the Becton–Dickinson and Codan connector, while it was significantly larger in the Tego^{TM} connector.

Figure 3 shows a photo and cross sectional view (not on scale) of the tested connectors, not attached to a luer device. After cutting the connectors along the longitudinal axis, internal dimensions of the hard plastic (black) and the silicon split septum (white) were added to the figure. Those pictures, however, fail to explain the experimental findings.

By attaching the connectors to a Bellco BL 307 dialysis tubing, we could observe the opening section of the connections in order to explain the measured differences in pressure drop. Table 1 gives an overview of the opening sections inside the three connectors when attached to other currently used dialysis tubings. The different pressure drops over the three connector types were found attributable to the position and opening system of the silicon split septum. Furthermore, since this septum might cause a different obstruction in both flow directions, pressure losses and with it, pressure drops, were not found equal for arterial and venous flow. Finally, most connector-tubing connections showed a connection play after screwing (closed *vs* loosen connection), even when the luer lock is fully tightened (Table 1). This resulted in some cases, in an even higher flow constriction when the connector is in its most loosen position, as the male of the tubing connector is not able to fully open the split septum.

While previous studies concerning the use of closed luer lock access devices on catheter hubs are only dealing with the microbiological efficacy avoiding catheter related infections, the present study set out to evaluate the occurrence of flow resistance. Although the silicon split septum was designed not to influence blood flow, the appliance of a closed luer lock access device was found to exert an additional resistance to flow, compared with the standard male-female luer connection. From the present experimental evaluation it can be concluded that the Tego^{TM} and Codan connector show promising results for the use on a catheter hub during and in between dialysis sessions. Further investigation is, however, necessary to evaluate *in vivo* the occurrence of blood haemolysis and to predict the period of usage without ensuing any obstruction and/or leakage.

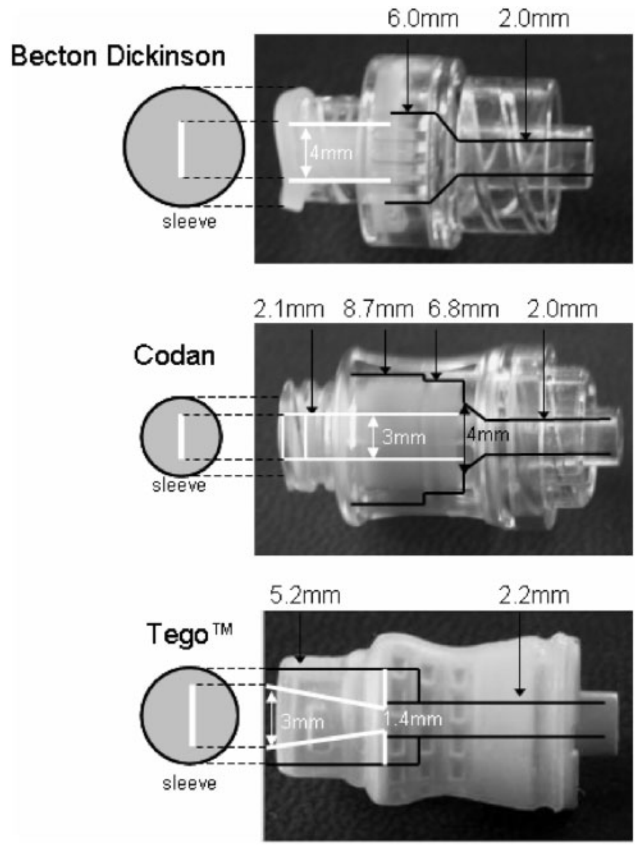

Fig. 3. Photo and cross sectional view of the tested connectors. The internal dimensions are indicated in black (hard plastic) and white (silicon split septum).

Conclusion

In order to diminish catheter-related infections with chronic haemodialysis patients, different types of closed luer lock access devices were designed to attach to the arterial and venous catheter hub. Several studies showed their significance of being a microbiological barrier, but since those devices stay in place during dialysis, it is also important that blood flow is minimally influenced. The present study revealed

Table 1. Overview of the opening size of the three connectors attached to different dialysis tubings

Tubings	Connection play			Opening section		
	BD	Codan	Tego	BD	Codan	Tego
BELLCO						
BL 307	yes	yes	yes	C: half open L: half open	C: open L: 3/4 open	C: open L: open
A5656-4 Formula 2000 BL307	yes	yes	yes	C: half open L: half open	C: open L: 3/4 open	C: open L: open
BL 360	no	no	no	half open	3/4 open	open
FRESENIUS						
CVVH-set	yes	yes	yes	C: open L: 1/4 open	C: open L: half open	C: open L: open
For Bellco Multimat	yes	yes	no	C: open L: 1/4 open	C: open L: half open	open
ALLMED						
For Bellco	yes	yes	yes	C: open L: 1/4 open	C: open L: half open	C: open L: open
BELDICO						
Y-piece for single lumen catheter	yes	no	yes	C: open L: half open	3/4 open	C: open L: open
GAMBRO						
AK10/100/200/95	no	no	no	1/4 open	3/4 open	open

Columns 2–4 indicate whether there is some connection play, after attachment to dialysis tubing, while columns 5–7 indicate the opening section. In the case of 'connection play', distinction is made between the opening section in the most closed position (C) and most loosen position (L). The opening section is indicated as being open, 3/4 open, half open, or 1/4 open.

that additional resistances to blood flow were minimal in the Tego^{TM} and Codan connector, while they were significant in the Becton–Dickinson connector. Furthermore, the degree of resistance was even depending on the type of dialysis tubing connected. Whether those resistances are in the safe range without the incidence of blood haemolysis, will be investigated in an *in vivo* study as planned for the near future.

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Conflict of interest statement. None declared.

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