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Modeling and Analysis of peritoneal dialysis piping set

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Abstract: With the number of end-stage renal disease (ESRD) patient population continues to increase. However ESRD patients rely on renal replacement therapy (renal transplantation and dialysis) to maintain a normal life. Design of a peritoneal dialysis tubing set, using three-dimensional design software SolidWorks; and dialysis the tubing set in SolidWorks flow simulation.

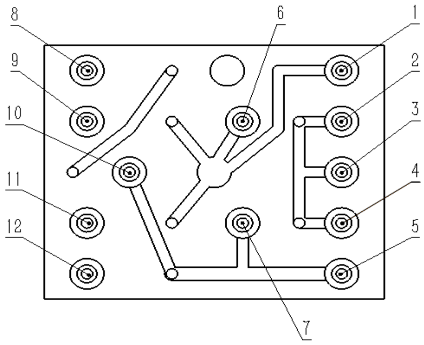
Key words: peritoneal dialysis; peritoneal dialysis pipingset

I. Introduction

Chronickidney diseasehasbecome one of themajor diseases thatthreatenpublichealth.End-stage renal disease(ESRD) is the end stage of chronic kidney disease, refers to irreversible renal function decline in patients rely on renal replacement therapy (renal transplantation and dialysis) to maintain a normal life pathological state needs[1].Dialysis can be divided into manual (continuous ambulatory peritoneal dialysis, CAPD) and automated peritoneal dialysis (automated peritoneal dialysis, APD)[2]。The traditionalperitoneal dialysis used to use gravity,and automated peritoneal dialysis machine uses a peristaltic pump and other external power mode. As one of the core components of peritoneal dialysis machine.It is particularly important for the design of dialysis tubing set.HuYue-ming and other domestic scholars proposed treatment of renal failure smart peritoneal dialysis system[3];Wang Hui put forward the design of automated peritoneal dialysis machine[4].The scholarsfocus onthe design of automated peritoneal dialysis machine, but less research on peritoneal dialysis tubing set.Design a dialysis tubing setbyusing three-dimensional softwareSolidWorks，and using SolidWorks flow simulation to simulation dialysate on pipingset in process of dialysate from heating interface topatient interface, and analysis the pressure drop, flow velocity distribution of dialysate.

II. Design piping set

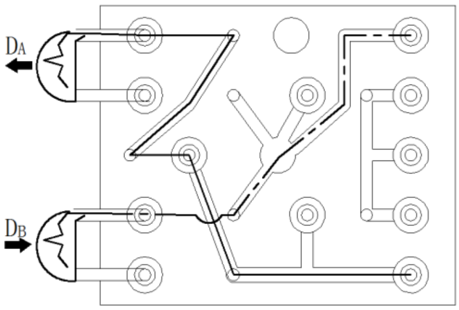
The main function of tub set are follows: Firstly, delivery the dialysateto the patient's abdominal cavity, then the dialysate is kept in cavity for some time；Secondly, the dialysis machine exhaust the dialysate through the piping set from the abdominal cavity. Specific peritoneal dialysis usually go through four processes: heating dialysate into the abdominal cavity; exhaust the waste dialysate out of the cavity ; pumping dialysate from supplement bag interface to the heating interface; pumping dialysate into the heating interface from the last bag interface. In this paper, based on the above four processes design a piping set.



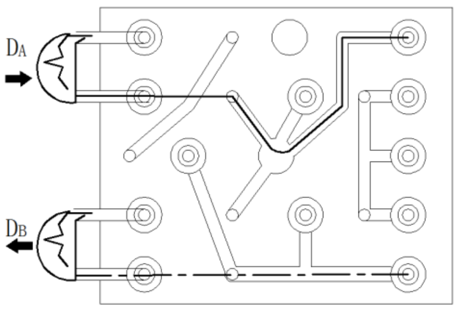
1.Patient interface valve 2.Waste dialysate interface valve 3.supplement interface valve 4.Last bag interface valve 5.Heating interface valve 6.7.10.reversingvalve 8.9.A power pump valve 11.12.B power pump valve

Figure 1Pipeline group two-dimensional map

The process of dialysate from heated interface to the patient interface can be de divided as following two sub-processes. D_A, $D_B$represent the pump which is connected with the piping set inFigure 2 (a) and Figure 2(b). The action of D_A, D_B aspirate and feed operation, respectively, using the left and right arrows indicate；Each process two pumps simultaneously and independently of each other；In Figure 2 (a) a solid line indicates the pumps A aspirate dialysate, the dashed line represents the operation of pump B feed liquid；So in Figure2 (b) the solid line representsthe pump A feed dialysate, the dashed line represents the pump B aspirate dialysate； when dialysate flow in the piping set, the valves which dialysate flow through the pipeline open.



(a)the sub-process of D_A aspirate, D_B feed



(b)the sub-process ofD_A feed, D_B aspirate

Figure 2 Dialysate from the heating process interface to patient interface

According to the peritoneal dialysis four dialysis process using SolidWorks software to build a three-dimensional model of peritoneal dialysis piping set, and it is shown in Figure 3.with three layers to optimize the structure ofPipeline group(the different treatment process piping design in hierarchical framework), it makes the pipeline group reduced volume, easy to carry.

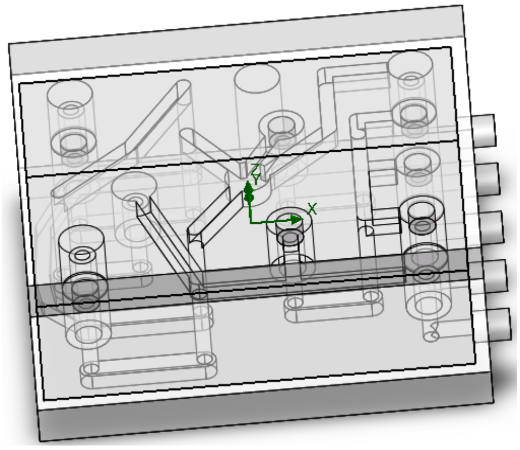


Figure 3 three-dimensional model of peritoneal dialysis pipingset

III. simulation

According to the requirements of peritoneal dialysis, automated peritoneal dialysis begin to work when in the dialysate heat at 37 ℃, then dialysate flow as certain rate to patients interface.As the actual dialysis process has a variety of modes, so the project simulate the tidal peritoneal dialysismodel. simulation the transient movement of dialysate as Figure 2(a) and 2(b).This article assumes heated dialysate flow in constant rate topatient interface through the pipeline group. The purpose of the simulation is to simulate a real dialysis process, intend to explore the feasibility of the pipeline group and get dialysate flow process in the pipeline group pressure, velocity and flow trajectories distribution.When SolidWorks flow simulation create a new project,You can use the wizard, and set the simulation parametersin accordance with Table 1 below.When you have finished setting the basic parameters in Table 1, after setting the boundary conditions：(1)by reference [2] tidal patterns，Inlet boundary conditions can be obtained：150~250ml/min（Thatis 2500~4200mm^3/s）and the model is set200ml/min。(2)Outlet boundary condition：Ambient pressure is standard atmospheric pressure (using Standard atmospheric pressureas value of abdominalcavity).

Table 1Basic Settings simulation project

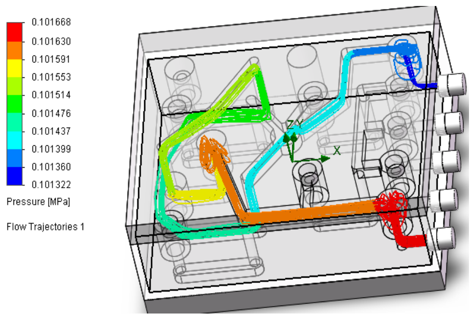
Item name	Setting Options
Configuration name	Create new：Dialysis tubing set simplified model
Unit system	NMM（mm-g-s）temperature(celsius)
Analysis type	TickInternal[exclude cavities without flow condition]
Physical features	Tick gravity，Setting 9.81m/s^2
Database of fluid	Choose liquid-water
Flow characteristic	Setting laminar and turbulent
Wall condition	Default wall thermal condition List, select adiabatic wall Roughness valve 0 micrometer
Initial condition	The initial temperature was set to 37 ℃
Result & geometry resolution	Setting results accuracy of 3

IV. Simulation Results and Analysis

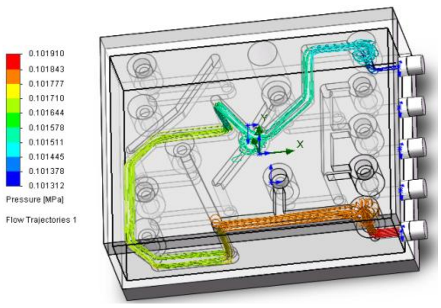
Now we analysis the sub-processes of dialysate from the heating interfaceto patient interface. And we are concerned about the pressure distribution, velocity distribution and the section of velocity distribution in patient interface.

4.1 Pressure distribution

Peritoneal dialysis pressure field distribution is shown in Figure 4.From Figure 4(a) we can learn about pressure range very little. the pressure drop is 0.0034 atm in the process of Figure 2(a) . Figure 4(b) is the sub-process-heating interface to patient interface, and pressure drop is 0.0059 atm. Figure 4a and Figure 4b shows that the pipingset to the dialysate pressure drop is very small. The pressure did not fluctuate severely during dialysis.



(a)the sub-process of D_A aspirate, D_B feed

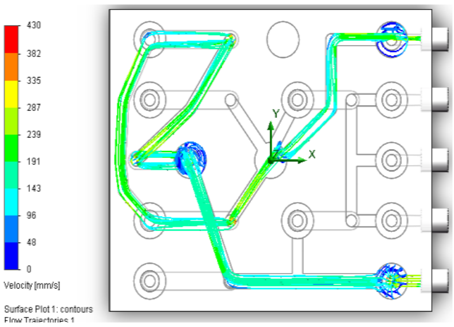


(b) The sub-process of D_A feed, D_B aspirate Figure 4 two sub-process pressures distribution

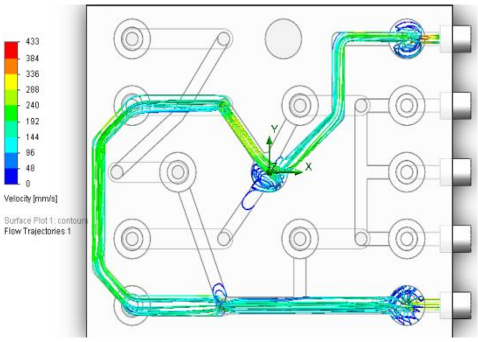
4.2Velocity vector field

The simulation in Fig. 5a and 5b corresponds to the FIG. 2a and 2b .they are the velocity vector field distribution of the two sub-processes. As can be seen from Figure 5 the overall dialysate flow is relatively flat, and the speedis concentrated in 287 ~ 96mm/s. Dialysate flow rate of loss among every unit length of the process is the same, and dialysate flow path of Figure 2(a) is longer than to Figure 2(b), so the maximum flow rate of the dialysate in Figure 5(b) is larger than Figure 5(a).Figure 6 is a cross-section of dialysis fluid velocity vector field shot into the patient interface, Figure 6(a) corresponds with 2(a) process. It shows patient interface velocity vector screenshot, while Figure 6(b) simulates 2(b) process speed vector screenshots. From Figure 6(a) and

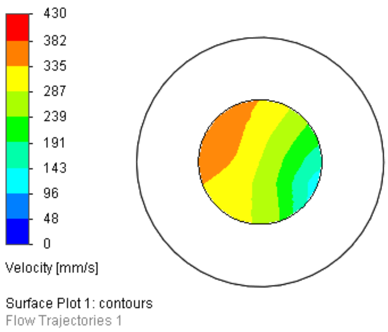
Figure 6(b)we know that the flow rate of the patient interface is concentrated in384~96mm/s.



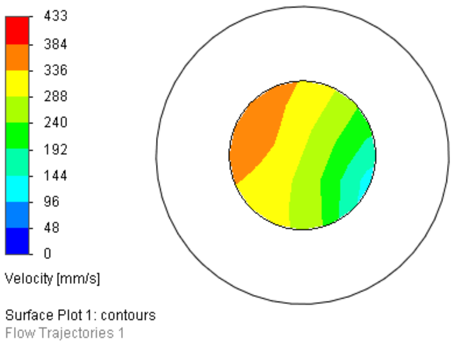
(a)D_A aspiration, D_B sub-process liquid feed



(b)the sub-process ofD_A feed, D_B aspirate Figure 5 two sub-process velocity vector field distribution



(a)the sub-process of D_A aspirate, D_B feed



(b)the sub-process ofD_A feed, D_B aspirate Figure 6 two sub process velocity vector-sectional view of the patient interface

V. Conclusion

(1) Using SolidWorks completes piping set design and takes fluid simulations to test our design. Through simulation we can get the fluid in the piping group pressure, velocity and fluid trajectory that can help us to improve the design level.

(2) Pressure distribution is shown in Figure 4 and Figure 6 speed vector shows that dialysate flow to the patient interface from the heating interface. During dialysis process piping group pressure drop is small and dialysate achieves lower speed, making a more gentle pace flow into the abdominal cavity.

(3) In this paper, using Solid Works to simulate the a peritoneal dialysis process, there are also some drawbacks. For example there are some deficiencies in the simulation medium by water instead of the dialysate.

References

[1] Liu Rongzhi Comparison of three peritoneal dialysis catheter complications and efficacy[D]. guang zhou: Southern Medical University, 2013

[2] Allen R. Nissen son, Richard N. Fine. Handbook of dialysis therapy [M].Taiwan: Elsevier Taiwan Inc, 2011

[3] Hu Yueming, Yuan Peng, Wu Xinsheng. Intelligent Peritoneal Dialysis System for the Treatment of Renal Failure [J].Journal of Biomedical Engineering, 2005, 22(6):1249~1252

[4] Wang Hui, He Jian-zhong, Zhao Man-man. Design of automated peritoneal dialysis machine [J].information technology, 2014, (4):121~124