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研究課題名（和文）血液透析による赤血球変形能変化の定量評価

研究課題名（英文）In vitro experiments on changes of erythrocyte deformability by the blood circulation in the hemodialysis circuit

研究代表者

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交付決定額（研究期間全体）：（直接経費） 3,200,000円

研究成果の概要（和文）：血液透析により赤血球変形能の変化が生じるかを確認するために、血液透析回路を循環した赤血球に対してマイクロチャンネル法と単軸引張法を用いてその変形能力を力学的に評価した。このとき実験は生体外模擬実験とし、実験条件は一般に臨床現場で用いられる条件を用いた。解析にはKelvinモデルを適用し形状回復時定数を変形能指標とした。実験の結果、透析時間に伴い溶血が生じる一方、両測定方法で時定数は透析時間や透析血流量により変化しなかった。これから現行の血液透析条件では赤血球の変形能力は正常な状態を確保されており、赤血球の変形能の視点からは患者QOLにあった透析条件について検討の余地があることが分かった。

研究成果の学術的意義や社会的意義

血液透析を必要とする患者は世界中で増加傾向になることが予想される。また現在の医療ではオーダーメイド医療など代表に、患者の社会的状況にも合わせた個々の治療法の実施が求められる。従来は溶血現象をもとに血液透析技術は発展しているが、本研究で用いた手法により力学的な視点から赤血球の変形能力を定量化することで、血液透析技術の研究開発に新たな指標を導入することができ、これにより患者の身体的負担をより軽減させQOL向上につながる設計開発が可能になると考えられる。

研究成果の概要（英文）：It is important to understand the influence of hemodialysis to erythrocytes in terms of mechanics in clinical development for dialysis patients. The deformability of erythrocytes in in-vitro circuit was measured by micro channel method and uniaxial stretching test. In this study, experimental condition was matched with that in clinical sites. In analysis, Kelvin model was used and time constant in erythrocyte's shape recovering process was used as a index of deformability. As a result, time constants obtained by two methods were not changed with dialysis time and blood flow rate, while hemolysis was progressed. This is seemed that erythrocytes in hemodialysis keep normal condition mechanically, which indicates the possibility of clinical improvement in personalized treatment for dialysis patients.

研究分野：生体医工学、機械工学

キーワード：赤血球 変形能 血液透析 マイクロチャンネル法 単軸引張法 時定数

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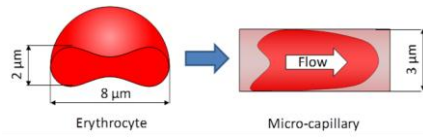


Fig. 1 Erythrocyte shape and deformation in micro-capillary.

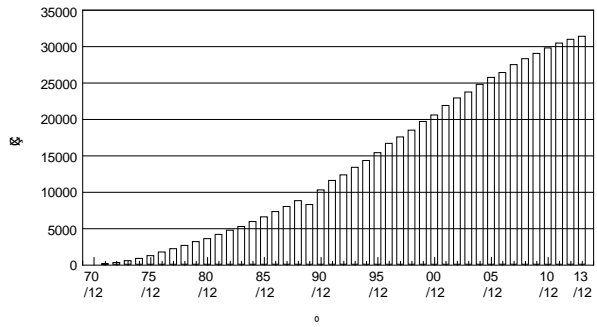


Fig. 2 Population development of dialysis patients.

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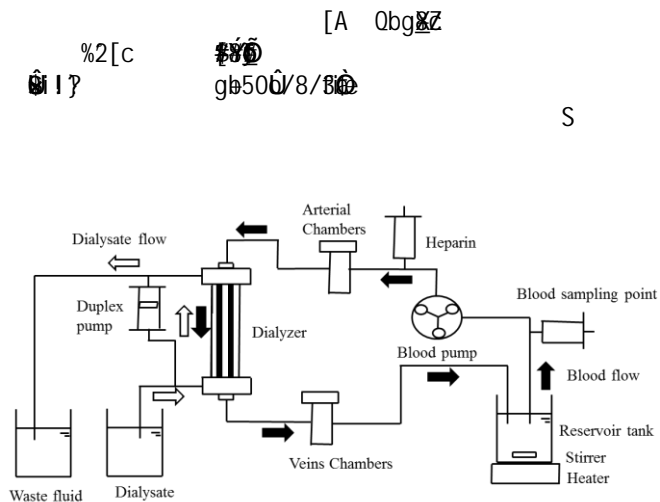


Fig. 3 Schematic diagram of a hemodialysis circuit.

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s8j 300bv0MG

Q_b = 100,

Q_b=100

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OD K\$2[c GP/KKS c^> 430 nm⁽³⁾ 2e/# c MC 2> (4)(5) 3H, c (6) 2e/# MC 2[c 42(7) 2e/# MAP (SOZ 2Y [i 2e/# PBS [j H_{ct}= 3% 5Ksvb Sv2vS ggG 3H, 2e/# ggC0bbfN K 1> # bvb 8 2[c3S9_ 60PW[2 bze/#H, 2e/# bggCfmg2v0C Kelvin model⁽⁷⁾ MC 2c Q_b=100, 200 ml/min 30W/83H, Qc Q_b=100, 200, 250 ml/min 30W/WS rS/Bi pH WZ pH bPmg+ DbSu2e/#Syb pH 9PMs8j XZ MC 2[1mS6 9c3082e/#KZWS9c pH 1WZ PBS 1.8% i 0.1ml 4P08 pH @ 5, 6, 7, 8, 9 1.17* 1 b9KS2e/#KZ MC 2[ggKS> 2>%2BY 3PIS/PKZ 30 3S 0 b5 i ODW 4 &gM Control c938(7)KS/PM 30 3S 0)Y6 6)P3008 30 3S 0 2e/# 3KS 30 3S 0 2e/# P/ @ 4/ MG &[1AsrS 30 3S 0 38KSTEb[c P/ 9#Ob 30 3S 0 30 3S 0 2e/#P/s8jK8WS /f5 8 v5vX P/ %° [4/M? WS 30 3S 0 v5cLb 9vZC/vWZe/SMc 30 3S 0 ~ [b0W 30 3S 0 0b8Y @ P/_ s8jK8c=C8 Su30 3S 0 4#P/4/Ø c/v0MZ 2 4CWS/P/c Control 0b\ 69 4 2sAgg 5 &gM W 5(a)c MC 0: S2e/ # MC 2 8S ggB)Y 5(b), (c), (d)&gM 93XPd(6)Y6 2e/#/MGAfbfbb60GG X +. OSY 6 &gMW 6(a)c 6 2e/#/M 6Abfbfbb60GG 6 &gMW 6(a)c 6 6(b), (c), (d)&gM #c MC 2[1/WS 3H, G 98Z Q_b=100 ml/min b2K0 Z 9r[2 460W 2A6\$} 1 146B60KRWSSu 6 2e/# 2e/# S8j @ ggB) 146B60KRWSSu c W 7 b|_ ggB^ &11 S ObSu6KZK bjg_=# @ --KC A8)Y WS 3H, 8Z8KSIK 9UZ 3 46B60KRWSSu 2e/# 2e/#s5M|AN 2e/# 3 46B60KRWSSu 6 S8j @ ggB) 146B60KRWSSu MC 2[30 6 2e/#M4(938) 2 46B60KRWSSu S3H , 2[c 30 6 &gM 2e/#M4(938) 2 46B60KRWSSu ggCfW 7 b6e/#pL[6WS MC 2[c&1WS6e G3H, 2[c MC 2[~ v - AFSu6\$} MC 2[c&1WS6e /#8'2, XV, PKZgg0gPKZ6' b9ggC0bbfbb60GG 30 3S 0 S3b| 69 2e/# 6 2e/# &1 7 46B60KRWSSu 6)g# 6: AFu c8SWS 6)g# rS pH 6KZ W 8 &gM|_ pH ggB [W 8%&61 (p<0.05)

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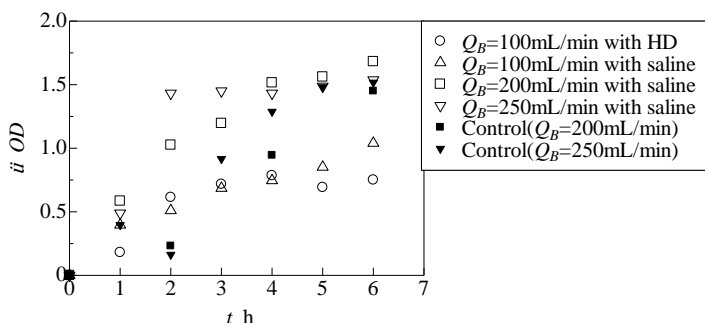
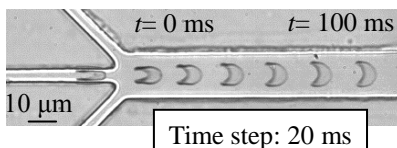
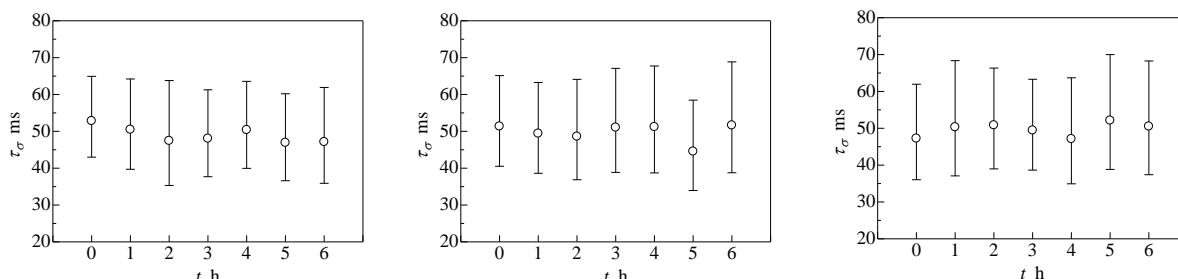


Fig. 4 Relationship between dialysis time and absorbance.

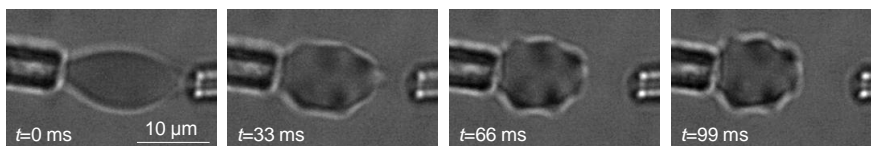


(a) Examples of RBC shape recovering process after getting out of a MC.

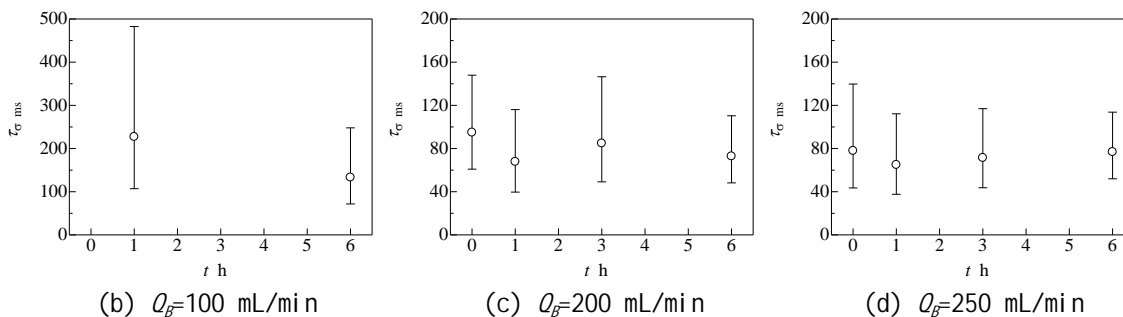


(b) $Q_B=100$ mL/min with dialysate. (c) $Q_B=100$ mL/min with saline. (d) $Q_B=200$ mL/min with saline.

Fig.5 Relationship between dialysis time and the time constant of shape recovery in MC method.



(a) Example of RBC shape recovering process after getting out from a micro-pipette.



(b) $Q_B=100$ mL/min

(c) $Q_B=200$ mL/min

(d) $Q_B=250$ mL/min

Fig.6 Relationship between dialysis time and the time constant of shape recovery in uniaxial stretching.

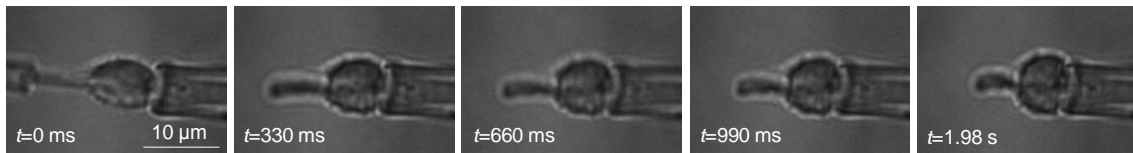


Fig. 7 RBC which did not recover its shape after getting out from a micro-pipette.

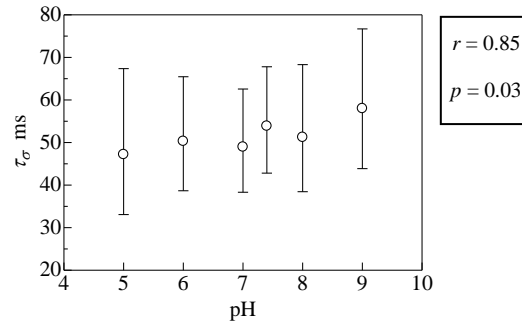


Fig. 8 Relationship between pH of dispersion medium and the time constant of shape recovery.

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