

Original Article

Acute hypotension after total knee arthroplasty and its nursing strategy

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Abstract: Objective: To determine the factors affecting postoperative acute hypotension after total knee arthroplasty (TKA) and provide a basis for guiding the clinical prevention. Methods: Between May 2001 and May 2013, a total of 495 patients undergoing routine TKA were analyzed retrospectively. Independent risk factors related to postoperative acute hypotension after TKA were determined by univariate and multivariate analysis. Results: Of the 495 patients undergoing TKA, 61 (12.32%) developed postoperative acute hypotension after surgery. Univariate analysis showed that preoperative Neu, time of surgery, time of anesthesia, pressure of tourniquet, time of using tourniquet, preoperative hypertension, age and type of surgery were significant influencing factors, whereas by multivariate analysis, only age, pressure of tourniquet and type of surgery were significant influencing factors. Conclusion: Factors those were associated with a significantly increased postoperative acute hypotension after TKA included age, pressure of tourniquet and type of surgery. Achieving a good preoperative and postoperative evaluation and monitoring vital signs and disease change contribute to the detection, intervention and salvage for the acute hypotension.

Keywords: Hypotension, total knee arthroplasty, total knee replacement

Introduction

Elderly trauma patients have poorer survival rates than younger trauma patients. This disparity stems from several contributors, including hypotension [1]. Hypotension is an abnormally low blood pressure (BP) in which end-organ perfusion becomes compromised. Although BP is not a direct correlate of tissue perfusion, it remains a noninvasive surrogate with clinical utility.

Total knee arthroplasty (TKA) is one of the most successful and commonly performed surgical procedures for the treatment of the late joint disease and restoration of the knee joint function [2-4]. However, because so many total knee arthroplasties are performed in elder patients, a number of patients are likely to develop acute hypotension after surgery. Previous MIMIC data (<http://www.physionet.org/challenge/2009>) have shown that mortality rates in patients with acute hypotension are as high as 37.8%. Therefore, clarifying the risk factors affecting the occurrence of postoperative acute

hypotension after TKA and setting out corresponding nursing strategy is important to avoid death and improve the success rate for salvage. The purpose of this study was to determine the influence factors affecting the occurrence of postoperative acute hypotension in patients undergoing TKA and provide the nursing strategy to guide the clinical prevention.

Patients and methods

The study was approved by the ethics committee of Xinqiao Hospital, the Third Military Medical University and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all subjects.

Between May 2001 and May 2013, a total of 495 patients (92 males and 403 females; age range 19 to 87 years) who underwent routine TKA were included in this study. Among them, 336 patients underwent unilateral TKA and the other 159 patients underwent bilateral TKA. Patient characteristics are presented in **Table**

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Table 1. Clinical data for 495 primary TKA patients

Index	Values
Age years	66 (19-87)
Sex, Male/Female	92/403
BMI, Kg/m ²	24.24 (15.01-31.47)
Dominant blood loss, ml	330 (0-2570)
Intraoperative transfusion of RBC suspension, ml	0 (0-1200)
Intraoperative transfusion of plasma, ml	0 (0-500)
Preoperative Blood Test	
HgB, g/L	121.0 (72-165)
Hct, %	37.0 (23.7-49.5)
Time of surgery, min	110.0 (40-470)
Time of anesthesia, min	150 (50-400)
Pressure of tourniquet, Pa	80 (50-80)
Time of using tourniquet, min	81 (30-348)
Cardiovascular disease risk factors	
History of Hypertension (%)	138 (27.9)
History of Coronary heart disease (%)	36 (7.3)
History of Smoking (%)	12 (2.4)
History of Drinking (%)	7 (1.4)
Type of surgery	
Unilateral TKA	336 (67.9)
Bilateral TKA	159 (32.1)
Type of anesthesia	
Spinal anesthesia	182 (36.8)
Epidural anesthesia	151 (30.5)
Combined spinal-epidural anesthesia	162 (32.7)
Postoperative analgesia (%)	
None	17 (3.4)
Cox2 ^a	247 (49.9)
Cox2+opioids ^b	231 (46.7)

Data were expressed as means \pm standard deviation (SD) or median as appropriate. BMI, body mass index; TKA, total knee arthroplasty; ^a, preoperative oral celecoxib capsules (400 mg) combined with intravenous injection of 40 mg parecoxib sodium within the postoperative 6 hours; ^b, preoperative oral 400 mg celecoxib capsules combined with intravenous injection of 40 mg parecoxib sodium within the postoperative 6 hours and oral estazolam tablets (2 mg) beyond the postoperative 6 hours.

1. Patients eligible for the study included those who underwent initial unilateral and bilateral TKA for primary osteoarthritis. Patients who underwent the TKA and had complete medical records were included. Patients who died of adverse event other than hypotension during the perioperative period were excluded. Patients who have insufficient data for statistical analysis were also excluded.

Surgical procedures

Of the 495 patients, 182 patients received spinal anesthesia, 151 received continuous epi-

dural anesthesia, and the other 162 received combined spinal-epidural anesthesia. The blocks were performed with the patient in the sitting position. Spinal anesthesia was performed through a 7 G spinal needle (Huaxing medical equipment industrial co., LTD, Jiangsu, China), introduced at the L₃₋₄ interspace. Depending on the age, height, weight and level of anesthesia of patient, 2-3 ml of ropivacaine 1% were injected. Intraoperative sedation with ice bag, COX2 or COX2 combined with opioid was administered at the discretion of the treating anesthesiologist and the patients demand. The block was performed by anaesthetists who were uninformed of the ongoing study. In patients receiving epidural anesthesia an epidural catheter (Huaxing medical equipment industrial co., LTD, Jiangsu, China) was introduced through a cranially directed 18 G Tuohy needle (Huaxing medical equipment industrial co., LTD, Jiangsu, China) in the L₂₋₃ interspace. After negative aspiration for blood or spinal fluid a test dose of 3 ml bupivacaine 0.5% with epinephrine was given. With the patient still in the sitting position titrated doses of 0.5% bupivacaine (3 ml +3 ml) were given. One to two minutes after the second dose, the patient was placed in the appropriate surgical position

and additional 3 ml-doses of bupivacaine 0.5% were given through the catheter until a T10 sensory block was achieved. Preservative-free morphine in 10 ml saline, 4 mg, was then administered through the epidural catheter. Combined spinal-epidural anesthesia was performed at the L₃₋₄ interspace (16-gauge/5-gauge Combined Spinal/Epidural Minipack; Tuoren medical equipment industrial co., LTD, Henan, China). Depending on the level of anesthesia of patient, 5-6 ml of ropivacaine 1% was injected. The patients were then placed in the supine or lateral position depending on the surgical procedure.

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Table 2. Univariate analysis of risk factors of acute hypotension after TKA

Variables	Hypotension (n=61)	Non-hypotension (n=434)	P value
BMI, Kg/m ²	23.92 (15.01-31.47)	24.37 (15.01-33.20)	0.698
Preoperative HgB, g/L	117.0 (91-146)	121.0 (72-165)	0.082
Preoperative HCT, %	36.48±3.14	36.97±4.22	0.273
Time of surgery, min	160.0 (65-320)	110.0 (40-470)	0.007
Time of anesthesia, min	180 (70-400)	150 (50-400)	0.020
Tourniquet time, min	119 (48-237)	81 (30-348)	0.007
Dominant blood loss, ml	300 (20-1400)	332.5 (0-2570)	0.824
Intraoperative transfusion of RBC suspension, ml	200 (0-800)	0 (0-1200)	0.239
Intraoperative transfusion of plasma, ml	0 (0-500)	0 (0-400)	0.789
Age, years			
<60	3 (5.2)	100 (23.0)	0.001
≥60	58 (94.8)	334 (77.0)	
Gender			
male	9 (14.8)	83 (19.1)	0.411
female	52 (85.2)	351 (80.9)	
Pressure of tourniquet, Pa			
50~60	2 (3.3)	73 (16.8)	0.014
65~70	10 (16.4)	80 (18.4)	
75~80	49 (80.3)	281 (64.7)	
History of Hypertension			
Negative	52 (85.2)	305 (70.3)	0.015
Positive	9 (14.8)	129 (29.7)	
History of Coronary heart disease			
Negative	52 (85.2)	400 (92.2)	0.308
Positive	9 (14.8)	34 (7.8)	
History of Smoking			
Negative	52 (85.2)	424 (97.7)	0.985
Positive	9 (14.8)	10 (2.3)	
History of Drinking			
Negative	59 (96.7)	429 (98.8)	0.406
Positive	2 (3.3)	5 (1.2)	
Type of surgery			
Unilateral TKA	28 (45.9)	308 (71.0)	0.000
Bilateral TKA	33 (54.1)	126 (29.0)	
Type of anesthesia			
Spinal anesthesia	14 (23.0)	168 (38.7)	0.057
Epidural anesthesia	23 (37.7)	128 (29.5)	
Combined spinal-epidural anesthesia	24 (39.3)	138 (31.8)	
Postoperative analgesia			
None	1 (1.6)	16 (3.7)	0.666
Cox2	31 (50.8)	216 (49.8)	
Cox2+opioids	29 (47.6)	202 (46.5)	

Data were expressed as means ± standard deviation (SD) or median as appropriate. BMI, body mass index; HgB, haemoglobin; Hct, haematocrit; TKA, total knee arthroplasty.

All TKAs were performed through a midline skin incision and a medial parapatellar capsular incision. A pneumatic tourniquet was applied to

495 patients during TKA and was not released before skin closure. For bony resection, an intramedullary alignment jig was used for the

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Table 3. Multivariate analysis of risk factors of acute hypotension after TKA

Parameters	Hypotension (n=61)	Non-hypotension (n=434)	Exp (B)	95.0% CI for Exp (B)		P value
				Lower	Upper	
Age, years						
<60	3 (5.2)	100 (23.0)		Reference		
≥60	58 (94.8)	334 (77.0)	5.511	1.674	18.135	0.005
Pressure of tourniquet, Pa						
50~60	2 (3.3)	73 (16.8)		Reference		
75~80	49 (80.3)	281 (64.7)	5.249	1.227	22.458	0.025
Type of surgery						
Unilateral TKA	28 (45.9)	308 (71.0)		Reference		
Bilateral TKA	33 (54.1)	126 (29.0)	2.670	1.520	4.690	0.001

TKA, total knee arthroplasty.

femur and an extramedullary device was used for the tibia. No patella was resurfaced. Posterior stabilized knee prostheses were used for the all patients. Drain clamping methods were performed according to previously reported methods [5] as follows. Briefly, the tube was clamped and closed completely for 30 minutes; then the clamp was partially released until blood started to flow out. If the flow of blood ceased, the clamp was partially released until the blood flowed once again. Finally the clamp was fully opened. The drains were removed at 48 hours and the volume of fluid at one, two, and 24 hours was measured. All of the procedures were completed by the same group of surgeons.

Research index

Anaesthetic technique, intraoperative blood loss, intraoperative tourniquet use or not was recorded. Hemoglobin (Hb) and hematocrit (Ht) levels were measured at 6 and 24 hours post-operatively. Patients with Hb <80 g/L or those who have exhibited symptoms of acute anemia received blood transfusion therapy. The amount of blood transfused was recorded. Standard monitoring was used throughout the intraoperative period, including heart rate, heart rhythm, blood pressure, respiration and oxyhemoglobin saturation. Hypotension was defined as systolic/diastolic arterial pressure of less than 90/60 mm Hg or a decrease of greater than 30% in systolic blood pressure compared with preoperative control levels.

Statistical analysis

Statistical analysis was done by a person not involved in patient care. All statistics were per-

formed with SPSS 18.0 (SPSS, Chicago, IL). T test or Mann-Whitney U Nonparametric test or Chi-square test was used to detect potential risk factors of acute hypotension after TKA as appropriate; Multivariate logistic regression analysis was applied to determine independent risk factors of acute hypotension after

TKA. Differences were considered statistically significant when $P < 0.05$.

Results

Sixty one (12.32%) patients finally progressed to acute hypotension after TKA. They are consisted of 9 males and 52 females with a range age of 19-81 years. For the analysis of the related factor of the acute hypotension after TKA, these 495 patients were subdivided to two groups: hypotension group (n=61) and non-hypotension group (n=434). Univariate analysis showed that preoperative Neu, time of surgery, time of anesthesia, pressure of tourniquet, time of using tourniquet, preoperative hypertension, age and type of surgery were significant influencing factors (**Table 2**), whereas by multivariate analysis, only age, pressure of tourniquet and type of surgery were significant influencing factors (**Table 3**).

Discussion

Analysis of the factors related to acute hypotension after TKA

TKA is a commonly performed procedure to treat degenerative joint disease after failure of conservative management. Total knee arthroplasty has excellent functional results and is one of the most successful procedures in medicine. However, many patients often have both knees involved, resulting in severe disability. In this study, 495 patients underwent routine TKA. Among them, 336 patients underwent unilateral TKA and the other 159 patients underwent bilateral TKA. Many surgeons feel that there is an increase in complications when

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simultaneous procedures are performed because of the increased operative time and blood loss under a single anesthetic. Several studies have demonstrated a greater incidence of cardiovascular complications [6-8], pulmonary embolus [9], postoperative neurologic changes [6, 10], and gastrointestinal complications [11]. In this study, we sought to determine if there was a greater danger with respect to the postoperative hypotension in performing simultaneous bilateral vs unilateral TKA. In our study, our results showed a statistically significant difference between operation type and postoperative hypotension, with a higher increased relative risk of postoperative hypotension when undergoing a bilateral TKA, as compared to the unilateral TKA.

The patient's age may also be a factor associated with postoperative hypotension. Elderly patients, especially complicated with cardiovascular disease are more likely to develop acute hypotension after TKA. In elderly people, the body cannot effectively regulate the tension in the blood capillary bed after surgery and the interstitial fluid cannot be transferred into the blood vessels in a timely manner [12]. Cardiovascular system of elderly people likely had poor stress compensatory ability. This will make it possible to develop acute hypotension. In addition, ischemia reperfusion injury after tourniquet release can also increase the risk of hypotension in elderly patients [13, 14]. In the study, we observed that patients ≥ 60 years had a higher incidence of postoperative acute hypotension following TKA compared to patients < 60 years, which was consistent with the previous opinions.

Tourniquets are widely used in total knee arthroplasty (TKA) [12, 15]. TKA has been reported to associate with significant blood loss. Although the tourniquet is widely used by orthopedic surgeons, its role is controversial [16]. Several studies have shown that using a tourniquet in TKA could reduce the total blood loss [15, 17], while results from others indicated the opposite [18-22]. Therefore relationship between the use of tourniquet and the total blood loss of patients undergoing TKA is still unclear. In our study, only patients using tourniquet during TKA was included due to completely eliminate the use of tourniquet during TKA may bring risk. The bone bed may have blood or fat on its surface and that this might compromise cementation [23]. Increased tourniquet

time may increase the risk of nerve injury or other complications [24, 25]. In the current study, univariate analysis showed that the increased tourniquet time and pressure had no significant effect on the postoperative hypotension. Therefore we believe in total knee arthroplasty (TKA) tourniquet time or pressure should be limited or reduced to prevent development of complications such as hypotension.

Spinal anaesthesia blocks the sympathetic efferent nerves that release norepinephrine onto vascular smooth muscle, the sinoatrial node, the atrioventricular node, the conduction system and the muscle cells of the heart [26]. The main complication of this anesthetic technique is intraoperative hypotension, especially in high-risk elderly patients including those with known cardiac disease [27]. Epidural anesthesia blocks the sympathetic nervous system causing resistance and capacity vessel vasodilation. Previous study have suggested a movement of fluid from the interstitial to the intravascular space after epidural anesthesia with hypotension based on hemoglobin measurements [28]. A common physiologic effect of epidural and spinal anesthesia is hypotension, primarily due to blockade of the sympathetic nervous system causing arterial and venous vasodilation with subsequent "functional" hypovolemia. In the present study, we observed that the incidence of the acute hypotension is statistically higher in patients receiving combined spinal-epidural anesthesia than that in patients receiving spinal anesthesia.

Nursing strategy

After thoroughly known of the history of disease and treatment, attention should be paid to monitor cardiovascular function, Hb and Hct levels, and coagulation status and hemostasis risk in patients before surgery. Patients who have exhibited symptoms of acute anemia should receive blood transfusion therapy to reach an Hb level of no less than 80 g/L. In addition, standard monitoring before surgery should be used in patients with cardiovascular disease, including continuous ECG, heart rate, non-invasive arterial blood pressure.

Postoperatively, detailed information about patients such as the surgical method, type of anesthesia, bone cement and tourniquet, tourniquet time, surgical time, vital signs change

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throughout the intraoperative period, and intraoperative blood loss and transfusion volume should be assessed by surgeons, anesthetists and operating room nurse to determine the suspicious high-risk patients with acute hypotension, particularly patients who had fall of blood pressure or bradycardia during the surgery.

In addition, after TKA surgery, all patients should be monitored such as continuous heart rate, heart rhythm non-invasive arterial blood pressure, and oxyhemoglobin saturation. Previous studies reported that arterial blood pressure, heart rate, and oxyhemoglobin saturation may be used as an effective tool to detect patients at high risk of acute hypotension [29-31]. In the study, 61 patients progressed to acute hypotension after TKA. Among these patients, 30 cases exhibited signs of increased heart rate, whereas 13 cases showed decreased heart rate. We also observed 9 cases showed decreased oxyhemoglobin saturation of at least 85 percent. Among these hypotensive patients, 6 occurred at 3 hours after surgery, while the remaining at 4-8 hours, suggesting that patients should be monitored carefully within 8 hours after surgery.

Additionally, among the 31 patients, 43 patients showed excitation, dysphoria, pale and clammy skin and complained of dizziness and chills before the falling of the blood pressure. 22 patients experienced nausea and vomiting. Blood pressure fall was observed after vomiting. 5 patients complained of blurred vision, blood pressure fall and heart rate reduction. They are easily cured by atropine and dopamine. If worsen wound or pain from other parts of the body occurred, care should also be taken to the possibility of the occurrence of acute hypotension after surgery.

Postoperative blood routine examination and arterial blood gas monitoring with appropriate frequency contribute to the avoidance of the acute hypotension. For high-risk patients, urinary output should be monitored within 24 hours after surgery. It should be noted that Hb and Hct levels under the condition of acute blood loss cannot accurately reflect the volume of blood loss, because the humoral regulation has not been mobilized to balance the sharp blood volume reduction. Therefore, blood pressure, pulse, central venous pressure and some other related parameters should be overall con-

sidered to prevent the incidence of the acute hypotension.

Finally, postoperative exercise such as active limb movements, active ankle movements, and isometric contractions of the quadriceps femoris may also contribute to the prevention of acute hypotension.

Conclusion

An age of more than 60 years, tourniquet pressure, and type of surgery were associated with postoperative acute hypotension after TKA. Pre- and postoperative evaluation and continuous monitoring of the vital signs and disease change contribute to the detection, intervention and salvage for the acute hypotension.

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Disclosure of conflict of interest

None.

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References

- [1] Oyetunji TA, Chang DC, Crompton JG, Greene WR, Efron DT, Haut ER, Cornwell EE and Haider AH. Redefining hypotension in the elderly: Normotension is not reassuring. *Arch Surg* 2011; 146: 865-869.
- [2] Hetaimish BM, Khan MM, Simunovic N, Al-Harbi HH, Bhandari M and Zalzal PK. Meta-analysis of navigation vs conventional total knee arthroplasty. *J Arthroplasty* 2012; 27: 1177-1182.
- [3] Nunley RM, Ellison BS, Ruh EL, Williams BM, Foreman K, Ford AD and Barrack RL. Are patient-specific cutting blocks cost-effective for total knee arthroplasty? *Clin Orthop Relat R* 2012; 470: 889-894.
- [4] Ishida K, Tsumura N, Kitagawa A, Hamamura S, Fukuda K, Dogaki Y, Kubo S, Matsumoto T, Matsushita T and Chin T. Intra-articular injection of tranexamic acid reduces not only blood loss but also knee joint swelling after total knee arthroplasty. *Int Orthop* 2011; 35: 1639-1645.

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- [5] Tsumara N, Yoshiya S, Chin T, Shiba R, Kohso K and Doita M. A prospective comparison of clamping the drain or post-operative salvage of blood in reducing blood loss after total knee arthroplasty. *J Bone Joint Surg Br* 2006; 88: 49-53.
- [6] Lane GJ, Hozack WJ, Shah S, Rothman RH, Booth RE Jr, Eng K and Smith P. Simultaneous bilateral versus unilateral total knee arthroplasty. Outcomes analysis. *Clin Orthop Relat Res* 1997; 106-12.
- [7] Ritter M, Mamlin LA, Melfi CA, Katz BP, Freund DA and Arthur DS. Outcome implications for the timing of bilateral total knee arthroplasties. *Clin Orthop Relat Res* 1997; 99-105.
- [8] Adili A, Bhandari M, Petruccelli D and De Beer J. Sequential bilateral total knee arthroplasty under 1 anesthetic in patients > or =75 years old: complications and functional outcomes. *J Arthroplasty* 2001; 16: 271-278.
- [9] Fabi DW, Mohan V, Goldstein WM, Dunn JH and Murphy BP. Unilateral vs bilateral total knee arthroplasty risk factors increasing morbidity. *J Arthroplasty* 2011; 26: 668-673.
- [10] Lynch NM, Trousdale RT and Ilstrup DM. Complications after concomitant bilateral total knee arthroplasty in elderly patients. *Mayo Clin Proc* 1997; 72: 799-805.
- [11] Lombardi AV, Mallory TH, Fada RA, Hartman JF, Capps SG, Kefauver CA, Dodds K and Adams JB. Simultaneous bilateral total knee arthroplasties: who decides? *Clin Orthop Relat Res* 2001; 319-329.
- [12] Zhang FJ, Xiao Y, Liu YB, Tian X and Gao ZG. Clinical effects of applying a tourniquet in total knee arthroplasty on blood loss. *Chinese Med J (English Edition)* 2010; 123: 3030.
- [13] Sullivan PJ, Sweeney KJ, Hirpara KM, Malone CB, Curtin W and Kerin MJ. Cyclical ischaemic preconditioning modulates the adaptive immune response in human limb ischaemia-reperfusion injury. *Br J Surg* 2009; 96: 381-390.
- [14] Cheng YJ, Wang YP, Chien CT and Chen CF. Small-dose propofol sedation attenuates the formation of reactive oxygen species in tourniquet-induced ischemia-reperfusion injury under spinal anesthesia. *Anesth Analg* 2002; 94: 1617-20, table of contents.
- [15] Tetro AM and Rudan JF. The effects of a pneumatic tourniquet on blood loss in total knee arthroplasty. *Can J Surg* 2001; 44: 33-38.
- [16] Tai TW, Lin CJ, Jou IM, Chang CW, Lai KA and Yang CY. Tourniquet use in total knee arthroplasty: a meta-analysis. *Knee Surg Sport Tr A* 2011; 19: 1121-1130.
- [17] Abdel-Salam A and Eyres K. Effects of tourniquet during total knee arthroplasty. A prospective randomised study. *J Bone Joint Surg Br* 1995; 77: 250-253.
- [18] Aglietti P, Baldini A, Vena L, Abbate R, Fedi S and Falciani M. Effect of tourniquet use on activation of coagulation in total knee replacement. *Clin Orthop Relat R* 2000; 371: 169-177.
- [19] Vandebussche E, Duranthon LD, Couturier M, Pidhorz L and Augereau B. The effect of tourniquet use in total knee arthroplasty. *Int Orthop* 2002; 26: 306-309.
- [20] Wakai A, Winter DC, Street JT and Redmond PH. Pneumatic tourniquets in extremity surgery. *J Am Acad Orthop Sur* 2001; 9: 345-351.
- [21] Wakankar H, Nicholl J, Koka R and D'Arcy J. The tourniquet in total knee arthroplasty: A Prospective, Randomised Study. *J Bone Joint Surg Br* 1999; 81: 30-33.
- [22] Yang ZG, Chen WP and Wu LD. Effectiveness and safety of tranexamic acid in reducing blood loss in total knee arthroplasty: a meta-analysis. *J Bone Joint Surg Am* 2012; 94: 1153-1159.
- [23] Fan Y, Jin J, Sun Z, Li W, Lin J, Weng X and Qiu G. The limited use of a tourniquet during total knee arthroplasty: a randomized controlled trial. *Knee* 2014; 21: 1263-1268.
- [24] Horlocker TT, Hebl JR, Gali B, Jankowski CJ, Burkle CM, Berry DJ, Zepeda FA, Stevens SR and Schroeder DR. Anesthetic, patient, and surgical risk factors for neurologic complications after prolonged total tourniquet time during total knee arthroplasty. *Anesth Analg* 2006; 102: 950-955.
- [25] Tarwala R, Dorr LD, Gilbert PK, Wan Z and Long WT. Tourniquet use during cementation only during total knee arthroplasty: a randomized trial. *Clin Orthop Relat R* 2014; 472: 169-174.
- [26] Sen S, Aydin K and Discigil G. Hypotension induced by lateral decubitus or supine spinal anaesthesia in elderly with low ejection fraction undergone hip surgery. *J Clin Monit Comput* 2007; 21: 103-107.
- [27] Sehat K, Evans R and Newman J. Hidden blood loss following hip and knee arthroplasty correct management of blood loss should take hidden loss into account. *J Bone Joint Surg Br* 2004; 86: 561-565.
- [28] Holte K, Foss NB, Svensén C, Lund C, Madsen JL and Kehlet H. Epidural anesthesia, hypotension, and changes in intravascular volume. *Anesthesiology* 2004; 100: 281-286.
- [29] Hanss R, Bein B, Weseloh H, Bauer M, Cavus E, Steinfath M, Scholz J and Tonner PH. Heart rate variability predicts severe hypotension after spinal anesthesia. *Anesthesiology* 2006; 104: 537-545.
- [30] Hanss R, Bein B, Ledowski T, Lehmkuhl M, Ohnesorge H, Scherkl W, Steinfath M, Scholz J and Tonner PH. Heart rate variability predicts severe hypotension after spinal anesthesia for elective cesarean delivery. *Anesthesiology* 2005; 102: 1086-1093.

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[31] Rocha T, Paredes S, de Carvalho P and Henriques J. Prediction of acute hypotensive epi-

sodes by means of neural network multi-models. *Comput Biol Med* 2011; 41: 881-890.