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Effects of Pneumatic Tourniquet on Knee Surgery

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REVIEW

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Abstract

The pneumatic tourniquet has been used in extremity surgery, especially in knee surgery. Both advantages and disadvantages were reported for using this co-operative instrument. The advantages, such as improving the surgical field and decreasing the blood loss were significant, however, disadvantages—such as increasing risk of deep vein thrombosis (DVT), nerve and muscle injuries—made its use controversial. In this review we evaluated the impact of the tourniquet on knee surgery, briefly focusing on its advantages and disadvantages in order to offer surgeons a more reliable guidelines. In previous studies there were several limitations in methodological design, tourniquet identifications, and post-operative anticoagulant regime, which made the results unreliable. Limitations such as not considering blinding assessors, assessing results with intention to treat principles, justification of sample size on the basis of power calculation and described cohort study were the most common problems in methodological designs. Lack of notification in assessing quality of life in tourniquet-used patients was a major problem which needs to be further evaluated. So we recommended designing a study that would preclude the aforementioned limitations.

Key Words
Tourniquet; Knee surgery; Review; Blood loss.

Background

The pneumatic tourniquet that can reduce intra-operative blood loss and increase the surgeon's visual field has been used in extremity surgery for more than a century. The tourniquet has been used extensively by orthopaedists worldwide due to its significant advantages [2-5] reported in earlier researches, such as shortening duration of procedures and improving cement bone inter-digitations [2,5,6]. However, further researches and studies determined disadvantages known as "post-tourniquet syndrome" [7]. Therefore, the orthopaedic surgical community has voiced concern about the use of the pneumatic tourniquet. We evaluated the impacts of tourniquet use on knee surgeries, focusing briefly on the advantages and disadvantages. The goal of this review study is to guide the surgeons to select better approach and to design better future studies without limitations.

Effects of tourniquet on peripheral nerves

Some investigations report the incidence of nerve injury in knee arthroscopies following tourniquet application to be nearly 7%; thus, most of the injuries (80%) were caused by tourniquets [8]. Nerve injuries are comprised of nerve paralysis and pain in the extremities, caused by axonal conduction delay and pressure on peripheral nerve ends. In addition, axonal conduction delay and pressure on peripheral nerve ends were due to hyperaemia and increase in limb size following tourniquet deflation [8-15].

Effects of tourniquet on muscles

Tourniquet application reduces muscular endurance, intensifies weakness and may cause decline in the patient's postoperative functions [16-19, 9]. Evaluating patients' electromyographies (EMG), demonstrated EMG abnormalities in surgeries performed with a tourniquet in upper and lower limbs, respectively 77% and 70%; while incidence of abnormalities in surgeries performed without a tourniquet was 3.4% and 0%, the previous studies suggest that clinically relevant tourniquet compression causes a secondary increase in vascular permeability, intraneural oedema, and subsequent prolonged tissue ischemia, resulting in nerve degeneration and EMG abnormalities [16,20]. Additional studies showed changes in 63% and 72% of the patients, respectively, [18, 19] that may persist up to six months after the surgery [16-18, 21-29]. Tourniquet use is associated with elevation of serum myoglobin [30, 31] and with rhabdomyolysis that in some cases is deteriorated by hypothyroidism [104]. In addition, Sheth et al. found an elevated risk of rhabdomyolysis with creatine supplement consumption. They argued that the rhabdomyolysis was due to ischemia from the intraoperative tourniquet application [32].

Effects of tourniquet on coagulation

Tourniquet application can elevate the risk of deep vein thrombosis (DVT) [33-35] (Figure 1.) through stasis, endothelial damage, and platelet aggregation [36-44, 3, 28]. However, Harvey et al. [4] have reported that there is no meaningful correlation between incidence of DVT and tourniquet application.

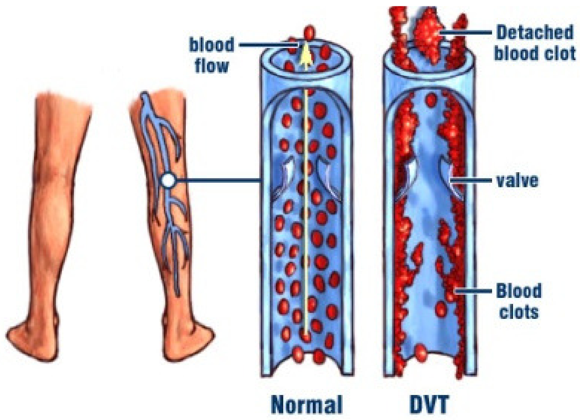

Figure 1. DVT

Physiologic changes during tourniquet application

Tourniquet application causes acid-base imbalance that can lead to pulmonary oedema [45, 46] and induces transendothelial migration of polymorphonuclears [47, 48]. Levels of phosphocreatine, glycogen, and ATP decline because of a shift to anaerobic metabolism. Further, the hypoxia caused by tourniquet fastening enhances probability of early infection and postpones wound healing up to 22% of all cases [49, 55]. After tourniquet deflation, tissue oxygenation occurs that generates reactive oxygen species (ROS) in ischemic tissue. These reactive oxygen species initiate formation of ischemia-modified albumin (IMA) and malonydialdehyde (MDA) in tissue and cell injury [56]. Moreover, cell injury is exacerbated by pre-inflammatory substances derived from polymorphonuclears (PMN) [47, 48]. Following cold-blood reperfusion in extremities under pressure after tourniquet deflation, core body temperature may fall—a fact which should be considered by surgeons, in order to prevent hypothermia in elderly patients [57, 58].

Discussion

Two distinct types of tourniquets are found in the surgical setting: 1- Non-inflatable (nonpneumatic) tourniquets contain gloves, penrose drain, simple rubber tubing and elastic bandage and plain cloth bandages. 2- Pneumatic tourniquets, which have cuffs that are inflated by compressed gas. The pneumatic tourniquet was used by Cushing (1904) as a device for reducing haemorrhage and increasing surgeons' visual field [1]. Various advantages and disadvantages were reported in previous studies, casting serious doubt among orthopaedists regarding the utility of tourniquet usage. Although various studies have been published, the majority of them have exhibited several methodological limitations, including that of not considering intervention factors during and after surgery. In these previous studies several methodological limitations, including not considering blinding assessors, assessing results on intention to treat principles, justification of sample size on the basis of power calculation and described cohort study, have rendered unreliable and contradictory results.

Of the studies in which several intervention factors were not taken into consideration, the biases in measuring the outcomes are obvious. These factors include: tourniquet position; applying or not applying padding beneath the tourniquet; width of the tourniquet cuff; insufficient comment on thromboprophylaxis and analgesics; and patient's postoperative management [59-60] (See Table-1). Decreasing blood loss and increasing surgeon's visual field are known benefits of tourniquet usage. However, only one conducted survey on the surgeon's visual field is available. That research had several limitations: justification of sample size with a power calculation was not done; results were assessed on an intention to treat; biases and methods of blinding the research for patients, surgeons and assessors may cause unreliable results. Designing a study which can resolve these specific problems is warranted.

Although a meta-analysis study has demonstrated bleeding reduction with tourniquet application, a study has reported that tourniquets do not affect postoperative blood draining and the need for transfusions [62]. In addition to routine bleeding during surgery, intra-articular bleeding and extravasation into the tissue—know as occult bleeding—are major matters of concern. However, occult bleeding due to tourniquet use is reported [63] from different points of view. Some proposed causes that have been suggested are: reactive hyperaemia [22, 64-65]; increased fibrinolytic activity [2, 65-67]; and function of generated superoxides after blood reflow. Furthermore, some studies have shown that administration of Prednisolone, Aloprinol, Catalase or superoxide dismutase lowers the complications of blood reflow [68-69].

Despite studies conducted to present the safest tourniquet time, appropriate time of deflation, ideal duration of tourniquet use, and optimum cuff pressure still remain challenging questions. Thus, various times have been reported for the onset of tourniquet complications from the time of application, such as 60, 75, 90, 120 and 180 minutes [7,18,23,25,28-29,70-78], even though one study stated that patients undergoing surgeries with tourniquet times of 60 minutes or more did not develop additional complications [61]. Measuring levels of creatine phosphokinase (CPK) in the distal zone with tourniquet usage in dogs demonstrates CPK elevation after two hours, while no increase is found after one hour [23, 28, and 72].

However, there is no difference between Tc-99 uptakes following one or two hours of tourniquet application [98].
Tourniquet deflation during surgery or after wound closure is also controversial. Although cuff deflation during the surgery is associated with better control of haemostasis, reduction of bleeding before surgery, and declining reoperation requirement [79-80], one survey nevertheless shows no obvious difference between reduction of bleeding and the need for transfusion [81].
Some investigators suggest additional solutions, including reperfusion intervals [15, 28, 23, 72, 74, and 82]. However, it should be noted that prolonged anaesthesia time involves the risk of inducing bleeding and oedema [28]. Most of the findings recommend applying the minimum possible cuff pressure in order to avoid disturbing the tissue microcirculation [83]. In order to achieve the desirable tourniquet pressure, certain techniques are recommended, including monitoring the patient's systolic pressure and distal pulsatile flow, as well as measuring limb circumference and applying cuffs that are sufficiently wide [27, 76, 84-89].
Studying nerve injuries relevant to tourniquet usage yields a variety of results. For instance, one study shows greater postoperative pain in patients undergoing total knee arthroplasty performed with a tourniquet [9]. Another study reports no pain increase and opioid administration after arthroscopic anterior cruciate ligament (ACL) reconstruction accompanied by tourniquet usage [90]. Such disagreement may be due to the difference between the durations of each of these procedures.
The fastening of tourniquets may affect nerve conduction [91]. Fowler et al. showed nerve conduction velocity (NCV) abnormalities with no decrease in action potential within two days after using tourniquets in baboons, which may be a result of myelin of membrane injuries without losing axonal continuity [92]. Non-physiological conditions caused by tourniquets, such as fibrinolysis and subsequent coagulation, enhance the risk of deep vein thrombosis [2-4, 93-94].
Although some investigators have noted as much as a 50% reduction in DVT in patients administering prophylactic anticoagulants [95], despite Abdel-Salam's study [9], the incidence of deep-vein thrombosis was measured to be lower in surgeries performed together with tourniquet application [96]. This difference may be due to a prophylactic diet with Warfarin or the possible biases of diagnosing asymptomatic small-calf thrombi via ultrasound.
In one study it was stated that systemic production of thrombin was not induced in knee surgery, despite the total hip arthroplasty [97]. This result may be due to the difference in design of the study approaches.
There are poorly evidences which evaluated appropriate activity and quality of life (QOL) after surgery with or without tourniquet used. Only one prospective, double-Blind, randomized clinical trial assessed the activities and QOL in patients who underwent knee arthroscopy with or without use of tourniquet during 3 months. They showed no statistically significant difference was found between tourniquet-used and without tourniquet groups for the Western Ontario and McMaster University Osteoarthritis Index (WOMAC) quality of life measure, functional tests, isokinetic muscle strengthening, or time to return to work or sport [98]. In view of this, such outcome measures should be evaluated more, in addition to performing a cost–benefit analysis of the application of tourniquets in knee surgery.

Conclusion

Prospective studies should be done to determine the probable biases and limitations. We also recommend an investigation to measure the quality of life in patients undergoing surgery with or without the application of tourniquets.

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PEER REVIEW
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CONFLICTS OF INTEREST
There is no conflict of interest to be declared.

Tables

Table1. Population characteristics and their main results.
(See next page.)

Legend:

T = Tourniquet
T + = Tourniquet assisted
T- = Tourniquet not assisted
mmHg= millimeters of mercury
N/ S = Not stated
SBP = Systolic blood pressure
TKR = Total Knee replacement
DVT = Deep venous thrombosis
ACL = Anterior Cruciate repair
TKA = Total knee Arthroplasty

Paper (date)	Surgery	Limbs	patients	T+	T−	Location	Pressure (mm Hg)	Duration (min)	Exsanguination	Thromboprophylaxis	Main Result
Hooper et al. (1999)	Arthroscopy	29	29	14	15	Thigh	300	N/S	N/S	N/S	T does not increase postoperative pain.
Wakankar et al. (1999)	TKA	77	77	37	40	N/S	Twice the SBP.	N/S	N/S	Low-dose warfarin	Deployment of Duplex ultrasonography for detecting DVT.
Clarke et al. (2001)	TKR	31	31	N/S	N/S	N/S	125 or at 250 mmHg above the patient's mean anaesthetic arterial blood pressure.	N/S	exsanguination in extension using a Rhys-Davies device where appropriate.	No patient received thromboembolic prophylaxis.	T induced wound hypoxia after TKR.
Abdel-Salam et al. (1995)	TKA	80	80	40	40	N/S	twice the systolic blood pressure	N/S	The limb was exsanguinated by elevation for two minute.	Fragmin, started two hours Preoperatively and continued postoperatively until the patient was fully mobile.	TKA can be safely performed without the use of the T.
Wakai et al. (2001)	Arthroscopy	26	26	N/S	N/S	Thigh	300	26	N/S	N/S	neutrophil transendothelial migration in t-ischemia has potential injury for tissue.
Reikera°s et al.(2009)	TKA	9	9	9	0	N/S	250–300 mmHg	100	Circumferential application of an elastic band was applied	subcutaneous injections of 5000 IU of low molecular heparin	after T deflation systemic activation of thrombin generation and fibrinolysis starts .
Bell et al. (2008)	TKA	939	939	939	0	N/S	N/S	N/S	N/S	patients received 10 mg of warfarin the evening before surgery or 5000 IU of dalteparin subcutaneously for 10 days beginning on post-operative day.	timing of T release influence blood loss or transfusion rates.
Steffin et al. (2009)	TKA	37	37	37	0	N/S	N/S	86 in early release and 111 in late.	Circumferential application with T.	Enoxaparin, 30 mg every 12 hours for 14 days	Not-relation between early and late T Release with a blood salvage Drain.
Li et al. (2009)	TKA	80	80	40	40	N/S	100 mmHg above the SBP.	N/S	Leg elevation and sealing with electric coagulation	low molecular weight heparin, pneumatic venous compression pumps and early mobilisation.	T increase hidden blood loss.
Arciero et al. (1996)	Arthroscopy	40	40	20	20	Thigh	150 above SBP.	87	Esmarch	N/S	lower T pressures may have little significant rehabilitative or functional cost to the patient.
Tibrewal (2000)	Arthroscopy	56	56	26	30	Thigh	N/S	N/S	N/S	N/S	No technical difficulties exist when T was not used.
Jarrett et al. (2004)	Arthroscopy	32	32	18	14	Thigh	250	17.1	Method N/S	N/S	Venous emboli were detected in 72% of patients used T.
Kirkley et al. (2000)	Arthroscopy	120	120	61	59	Thigh	N/S	30.5	N/S	N/S	The use of a T at 300 mm Hg does not effect patient quality of life or functional outcome .
Daniel et al. (1995)	Arthroscopy	94	94	48	46	Thigh	280	94	N/S	N/S	ACL surgery can be performed expeditiously without a T.
Thorblad et al. (1985)	Arthroscopy	19	19	9	10	Thigh	450	26.1	N/S	N/S	T increase postoperative pain and stiffness.