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Optimal Setting of Constant-Pressure Tourniquets Based on Limb Occlusion Pressure

It is now well established in the orthopedic, anesthesia and research literature that the optimal guideline for setting the pressure of a constant-pressure tourniquet is based on "Limb Occlusion Pressure".

"Limb occlusion pressure (LOP)" can be defined as the minimum pressure required, at a specific time in a specific tourniquet cuff applied to a specific patient's limb at a specific location, to stop the flow of arterial blood into the limb distal to the cuff. Similar definitions have been given by Reid et al [14], Pedowitz et al. [13] and Davies et al. [3].

The currently established guideline for setting tourniquet pressure based on LOP is as follows:

1) For single-bladder tourniquet cuffs of any width and type that are applied to the upper limb of an adult, tourniquet pressure should be set at **LOP plus 50 mmHg [14]**

2) For single-bladder tourniquet cuffs of any width and type that are applied to the lower limb of an adult, tourniquet pressure should be set at **LOP plus 75 mmHg [14]**.

3) For dual-bladder (Bier block) tourniquet cuffs of any width and type applied to an adult, LOP should be measured for each bladder and tourniquet pressure should be set at the higher **LOP plus 100 mmHg [3]**.

4) Pediatric guidelines based on LOP are currently being investigated.

The concept of setting tourniquet cuff pressure based on LOP was first suggested by Harvey Cushing in 1904, when he stated that an improved technique for setting tourniquet cuff pressure would be to insert a manometer in the tubing between the tourniquet cuff and pump, measure the minimum level of pressure necessary to stop arterial flow past that cuff (LOP), and then maintain the tourniquet cuff pressure slightly

above that level [2]. In 1973 Sanders suggested that, for increased safety, tourniquet pressure should be set at the 'minimum effective pressure', because there was no 'maximum safe pressure' [15]. Subsequently, convincing studies have confirmed that setting tourniquet pressure at the 'minimum effective pressure' is best achieved by measuring LOP and adding an additional pressure margin to offset intra-operative variables, resulting in the specific guidelines given above [3,14]. Practical implementation of these guidelines has been made possible by the introduction of increasingly accurate and reliable automatic tourniquet instruments during the past 20 years, eg see [1,6,7,9]. In addition, the more recent introduction of wide cuffs and cuffs having better designs has facilitated the routine use of very low tourniquet pressures, eg see [4,5,13]. Most recently, experimental tourniquet prototypes which incorporate automatic measurement of LOP directly into the instrumentation have been developed and are currently being evaluated in surgery [8,10,12,16].

Basing tourniquet pressure settings on LOP is better than older methods and guidelines based on "standard" settings at fixed pressure levels, or based on a patient's systolic blood pressure. For example, setting tourniquet pressure to standard levels assures that the pressure will generally be too high or too low; this is not the best practice, as it is well established in the literature that over-pressurization of the cuff is associated with a higher probability of nerve injury and other soft tissue injuries, and under-pressurization is associated with the leakage of arterial blood distally (eg see [9]), and anesthetic agent proximally in Bier block procedures [3,11, 16]. Alternatively, setting tourniquet pressure as a function of a patient's pre-operative systolic blood pressure is inadequate and not the best practice, as it does not take into account adjustments that must be made due to differing cuff widths, differing degrees of match between cuff shape and limb shape, differing degrees of snugness of cuff application to the limb, and differences in the characteristics of the limb tissue beneath the cuff [8,11,13, 16]; in contrast, setting tourniquet pressure as a function of LOP inherently takes into account all of these variables.

LOP can be measured in two basic ways, for a specific cuff applied to a specific limb at a specific limb location. First, cuff pressure can be increased slowly from zero while monitoring the pulse in an artery distal to the cuff until the distal pulse disappears; the lowest cuff pressure at which the pulse disappears can be defined as the ascending LOP. Second, cuff pressure can be decreased slowly (1mmHg/s) from a high occlusive level while monitoring an artery distal to the cuff until a distal pulse resumes; the highest pressure at which pulsatile flow first resumes can be defined as the descending LOP. The mean of the ascending and descending LOP can be used as an estimate of the true LOP. Monitoring of the distal pulse can be done conveniently by palpation, Doppler ultrasound or photoplethysmography (such as a pulse oximeter sensor). Automatic monitoring of the distal pulse and automatic estimation of the LOP by tourniquet instrumentation may save time and improve the consistency of LOP estimates [8].

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