Regional anaesthetic technique and the incidence of tourniquet pain

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The influence of regional anaesthetic technique on the incidence of lower extremity tourniquet pain was evaluated. We studied 60 patients undergoing orthopaedic procedures of the lower extremity with the use of a pneumatic tourniquet and anticipated inflation of 60 min or longer. Three different anaesthetic techniques were selected by random card draw: spinal anaesthesia (SAB) with plain 0.5% bupivacaine (15 mg) and 0.2 mg epinephrine added, lumbar epidural anaesthesia (EA) with 2% mepivacaine and 1:200,000 epinephrine added, and epidural anaesthesia (AEA) with the same solution alkalinized with bicarbonate. Onset and level of sensory blockade were determined by loss of painful sensation to pinprick. The incidence of tourniquet pain was determined at 15-min intervals or by patient complaint, by an observer unaware of group. Time to onset of pain, amount of treatment (iv fentanyl), and sensory level at the time of pain were determined. The SAB was compared with EA and AEA, and EA was compared with AEA. The SAB group was older. The sensory level achieved and duration of tourniquet inflation did not differ among groups. The incidence of tourniquet pain was lower with SAB than with EA and lower with AEA than with EA. There was no difference between SAB and AEA. This study demonstrated a lower incidence of tourniquet pain with spinal anaesthesia than with epidural anaesthesia to the same sensory level. However, this advantage is eliminated if the epidural anaesthetic was performed with an alkalinized local anaesthetic.

Nous avons évalué l'influence des techniques d'anesthésie régionale sur la douleur causée par un garrot au niveau du membre

Key Words

ANAESTHETIC TECHNIQUE: regional, spinal, epidural;
ANAESTHETICS, LOCAL: bupivacaine, mepivacaine.

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inférieur. Nous avons étudié 60 patients subissant une intervention orthopédique du membre inférieur avec utilisation d'un garrot pneumatique prévu pour 60 minutes ou plus. Trois techniques anesthésiques différentes ont été utilisées aléatoirement: anesthésie rachidienne (AR) avec de la bupivacaine 0,5% (15 mg) adrénalinée extemporanément à une concentration de 1:200 000, anesthésie épidurale lombaire (AE) avec 2% mepivacaine et 1:200 000 d'adrénaline et anesthésie épidurale avec la même solution mais alcalinisée au bicarbonate (AEA). Le début et le niveau du bloc sensitif sont déterminés par la perte de sensation à la pique. L'incidence de la douleur du garrot a été évaluée à 15 minutes d'intervalle ou en cas de plainte du patient par un observateur ignorant la technique d'anesthésie. Le délai d'apparition de la douleur, l'importance du traitement (Fentanyl iv) et le niveau sensitif au moment des plaintes ont été notés. L'AR est comparée à l'AE et à l'AEA, et l'AE est comparée à l'AEA. Le groupe AR se compose de patients plus âgés. Le niveau sensitif du bloc obtenu et la durée du garrot sont semblables dans tous les groupes. L'incidence de la douleur due au garrot est plus basse avec l'AR par rapport à l'AE, et plus basse avec l'AEA qu'avec l'AE. Il n'y a pas de différence entre l'AR et l'AEA. Cette étude démontre une incidence plus basse de douleur due au garrot avec l'anesthésie rachidienne qu'avec l'anesthésie épidurale pour un même niveau de bloc sensitif. Cependant, cet avantage de l'AR est perdu si l'anesthésie épidurale se réalise avec un anesthésique local alcalinisé.

Pneumatic tourniquets are often used to provide a bloodless operating field during lower-extremity surgery. Their use is associated with a variety of intraoperative effects, including hypertension, tachycardia, increased temperature during general anaesthesia, and pain during otherwise adequate regional anaesthesia.¹⁻⁸ During regional anaesthesia, a poorly localized, diffuse pain is felt by the patient at variable times after tourniquet inflation, despite adequate sensory blockade. This tourniquet pain is related to the duration of inflation and not to inflation pressure, although greater pain has been reported when larger cuffs are used.⁹

Different regional anaesthetic techniques result in different incidences of tourniquet pain. Spinal anaesthesia

has been shown to be more effective in preventing tourniquet pain than epidural anaesthesia.¹⁰ With spinal anaesthesia, bupivacaine is superior to tetracaine.^{7,11} The addition of glucose to spinal anaesthesia is associated with a higher incidence of tourniquet pain,⁵ while a variety of additives, morphine,¹² and clonidine¹³ decrease the incidence.

Alkalinization of local anaesthetics has been shown to decrease the latency to onset of a variety of regional anaesthetics including epidural anaesthesia.^{15,16} Other clinical effects include wider spread of blockade and increased duration.¹⁷ The purpose of this study was to determine whether the alkalinization of mepivacaine alters the incidence of tourniquet pain compared with epidural anaesthesia without added bicarbonate and spinal anaesthesia.

Methods

After obtaining the permission of the Institutional Review Board, written informed consent was obtained from three groups of 20 patients each scheduled to undergo orthopaedic surgery on the lower extremity using a pneumatic tourniquet. Only patients in whom the anticipated inflation time was greater than 60 min were selected. The patients were randomized by card draw into three groups, spinal anaesthesia (I) with 15 mg, plain bupivacaine with 0.2 mg epinephrine or epidural anaesthesia with 20 mL, 2% mepivacaine, 1:200,000 epinephrine with either saline (II) or bicarbonate 1 mEq · mL⁻¹ (III) added. The pH and PCO₂ of these solutions were measured in a non-clinical setting. All patients receiving an epidural anaesthetic had a catheter placed and the local anaesthetic (10 mL) was repeated if two-segment sensory regression was reached before the conclusion of surgery. The level of regional block and the time to onset of anaesthesia were determined by an observer unaware of the patient's group. Sensory onset was defined as a lack of awareness of sharp sensation from pinprick at L₁. Motor onset was defined as an inability to flex the hips or knees. Pain was evaluated by questions asked by an observer unaware of the treatment group. If pain was reported, the level of block was assessed to rule out failed or resolved regional block and the pain was treated with fentanyl 50 mg, *iv*. The duration of tourniquet inflation when pain was detected was recorded. Cases with pain-free tourniquet times of less than 60 min were excluded. Groups were compared with Fisher's exact test, Wilcoxon's rank sum test, and paired *t* test with Bonferroni's correction for comparison of multiple groups and considered significant at $P < 0.05$.

Results

Twenty patients were acquired for each group. One pa-

tient from Groups I, and II and five patients from Group III were excluded for having tourniquet inflation of less than 60 min and no tourniquet pain. The demographic characteristics (age, height, weight, ASA physical status) were comparable among all groups except for an older age in Group I (spinal) compared with the other three groups. The pH of the solutions was 5.56 for mepivacaine with saline and 7.31 for mepivacaine with bicarbonate averaged over three determinations. The PCO₂ was 210 mmHg in the alkalinized group over three determinations.

The sensory level achieved with the blocks was comparable among procedures. There were no failed blocks or complications. Four patients in Group II required re-dosing of the epidural before the conclusion of surgery for two-segment regression and five in Group III. This was not different. The mean tourniquet times were not different among groups, nor was the time to onset of tourniquet pain. The incidence of tourniquet pain was higher in the plain epidural groups (II) than in both the spinal Group (I) ($P < 0.01$) and the alkalinized epidural Group (III) ($P < 0.05$) (Table I). There was no difference in tourniquet pain between spinal and alkalinized epidural groups. Alkalinization accelerated the onset of both motor and sensory block with epidural anaesthesia (Table II).

Discussion

These results establish that the incidence of tourniquet pain is related to anaesthetic technique. When compared with conventional epidural anaesthesia, spinal block appears to be superior in the prevention of tourniquet pain. However, when the epidural technique is performed with alkalinized mepivacaine, this advantage is eliminated. This suggests an improved quality of epidural anaesthesia when performed with alkalinized mepivacaine.

Although this study confirms the influence of anaesthetic technique on the incidence of tourniquet pain, the exact cause of pain remains unclear. In each patient with pain, the sensory level of the block was higher than the dermatomes involved in either the surgery or even the tourniquet itself. Many theories have been advanced to explain the phenomenon. Because of the poorly localized quality of the pain, Hagenouw⁹ proposed a direct ischaemic effect on the nerve trunk, or the sensory innervation of the major arteries due to local products of anaerobic metabolism. This idea is supported by the absence of a similar pain during aortic clamping for peripheral vascular surgery and the slow resolution of the pain during reperfusion after tourniquet release.

Another explanation concerns the differential blockade of different fibre types. Rocco¹⁷ found a differential zone between the level of anaesthesia to pinprick and light

TABLE I Incidence of tourniquet pain

	Number	Level thoracic mean (SEM)	Tourniquet time (min) mean (SD)	Time to tourniquet pain (min) mean (SD)	Tourniquet pain
Spinal (I)	19	7.7 (1.4)	122.1 (21.8)	77	1
Epidural (II)	19	7.3 (2.5)	112.2 (33.4)	75.6 (28.4)	9
Epidural (III)	15	7.5 (1.6)	103.6 (26.8)	60	1

	Tourniquet pain	P value	Test
I < II		P = 0.008	Student's t
III < II		P = 0.047	Fisher's exact
II < III		P = 1.00	Fisher's exact

TABLE II Onset times

	Number	Motor (min) Mean (SD)	Sensory (min) Mean (SD)
Epidural (II) saline	19	16.7 (4.9)	10.8 (3.9)
Epidural (III) HCO ₃	15	6.0 (3.2)	3.3 (1.2)

Motor III < II $P < 0.001$; Sensory III < II $P < 0.001$; Student's t test.

touch during spinal anaesthesia. While the level of anaesthesia to pinprick had no correlation to tourniquet pain, assessment of level of anaesthesia to light touch was a good indicator of tourniquet pain. The zones of differential blockade are even greater during regression of the block which is more likely near the conclusion of surgery when tourniquet pain is most often reported. Regression of the block was not an issue in our patients.

On a more basic level, the gate theory of Melzack and Wall may be involved.¹⁸ Larger nerve fibres are postulated to inhibit the central effect of smaller A-delta and C-fibres in the dorsal horn of the spinal cord, and tourniquet pain is accentuated by effective blockade of larger A-beta fibres. Repetitive stimulation accentuates the impulses of the smaller fibres, and the repetitive stimulus may be the tourniquet.* Repetitive stimulus may even penetrate marginal areas of the block.¹⁷ This presents the combination of increases nociceptive conduction (A-delta, C-fibres) with decreased inhibitory modulation (A-beta). In the presence of repetitive nociceptive stimulus, fibres normally conducting only touch may become nociceptive.¹⁹ This combined theory helps to explain the absence of a positive effect of sympathectomy on the incidence of tourniquet pain.²⁰ Chabel²¹ provided support-

ing evidence for this theory with microfilament recordings showing slow firing, slow conductance activity in fibres not active before tourniquet inflation in animals. The recordings did not indicate, however, whether this activity followed somatic nerves or partially or completely entered the sympathetic system.

Considering the complex mechanism of tourniquet pain, it is not surprising that its incidence is influenced by anaesthetic technique. With spinal anaesthesia, a number of variables has been established. Bridenbaugh⁵ compared spinal anaesthesia with bupivacaine with and without added glucose. The incidence of tourniquet pain was higher in the glucose (hyperbaric) group and seemed to be related to the density of the lower segments of the block. Bonnet⁸ did a similar study with tetracaine and could not demonstrate a difference. Concepcion⁷ demonstrated an advantage with bupivacaine compared with tetracaine. They postulated that small C-fibres (known to be responsible for slow conductance and poorly localized pain) became unblocked sooner than other fibre types with tetracaine and not with bupivacaine. Evidence of differential sensitivities of C-fibres *in vitro* by Gissen²² supports this hypothesis. During regression of the block, tetracaine-blocked C-fibres became active sooner than bupivacaine blocked fibres. Stewart⁶ also supported this hypothesis with *in vitro* results that establish an enhanced frequency-dependent block of C-fibres with bupivacaine compared with tetracaine. Increased stimulus frequency is known to occur with tourniquet inflation.²¹

The favourable effect of alkalization of epidural mepivacaine on the incidence of tourniquet pain may also fit these explanations. Alkalization decreases the onset time of epidural anaesthesia,^{14,23,24} specifically epidural mepivacaine.¹⁴ This effect is mediated by an increased concentration of the non-ionized form of the local anaesthetic molecule which facilitates nerve cell membrane penetration. An increase in extracellular PCO₂ encour-

*Strichartz G. Zimmerman M: An explanation for pain originating from tourniquets during regional anesthesia. Reg Anesth 1984; 9: 44-5.

ages intracellular diffusion of CO₂ which would decrease the intracellular pH and facilitate the inward diffusion of the non-ionized form by increasing the concentration gradient.²⁵ Differences in PCO₂ between alkalinized solutions may explain the varied results despite similar pH among different studies.

Some studies have shown other influences on the quality of the block in addition to the effect on the onset time of some local anaesthetics. McMorland,^{23,24} with epidural bupivacaine, and Candido,¹⁶ with mepivacaine for plexus blockade, found an increased duration of blockade. Cousins and Bromage²⁶ found prolonged duration as well as increased density and spread of caudal epidural anaesthesia, which is thought to be mediated by a mechanism analogous to bicarbonate alkalization. The mechanism of altered block quality is unknown but may be related to biochemical factors acting during the initial onset of the block. If not alkalinized, the acidic local anaesthetic must be buffered in the extracellular space. While this occurs, diffusion may decrease the effective delivered concentration. It may be that alkalinized solutions deliver higher concentrations to the ultimate destinations, and because fibre types have concentration-specific block characteristics, more complete blockade may occur. Alternatively, frequently-specific blockade may be facilitated.

This study confirmed the lower incidence of tourniquet pain with spinal anaesthesia than with epidural anaesthesia found by Pitkänen.¹⁰ However, alkalization of epidural mepivacaine eliminated this difference. It is unclear if this would have been the case in the Pitkänen patients, because etidocaine, like bupivacaine, cannot be as effectively alkalinized as mepivacaine because of precipitation. The decrease in tourniquet pain achieved with additives to local anaesthetics for central blocks is not surprising; it occurs with clonidine¹² and morphine.¹¹ The favourable influences of these additives in the case of adrenergic agonists is explained by the suppression of nociceptive transmission at the spinal cord level with adrenergic agonist injection independent of local anaesthetic.²⁷ There may be an additive or even synergistic effect. The superiority of intrathecal local anaesthetic may be related to the higher relative concentration of local anaesthetic delivered directly to nervous tissue without the diffusion necessary for epidural blockade.

In summary, the incidence of tourniquet pain is specific to the regional anaesthetic technique. Spinal anaesthesia with isobaric bupivacaine with epinephrine is superior to epidural anaesthesia with mepivacaine and epinephrine, unless the epidural solution is alkalinized. Increased density or decreased differential blockade may be the effect of alkalization.

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