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EtCO2 Changes After Tourniquet Deflation in Orthopaedic Surgeries.

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ABSTRACT

Background: Orthopaedic surgeries of upper and lower limb extremities often require a tourniquet as it enables a surgeon to work in a bloodless operative field. The changes occurring due to tourniquet inflation and deflation may go unnoticed in ASA I & ASA II patients. However they may be significant in higher risk group. We planned this observational study to determine the changes occurring in EtCO2 after toutniquet deflation in orthopaedic surgeries. **Methods:** Study was conducted in 100 patients, belonging to ASA grade I & II, 18 – 65 years of age, posted for elective & emergency upper or lower limb surgery requiring tourniquet. At the end of surgery pre release EtCO2 was recorded. Then after deflating the tourniquet EtCO2 was recorded at following intervals – 0 minute (just after deflation of tourniquet), then at 1, 5, 10, 15, 20 and 30 minutes. **Results:** Increase in EtCO2 following tourniquet release was reported in all type of anaesthesia cases. **Conclusion:** There was a peak rise in EtCO2 at one minute in all type of anaesthesia cases.EtCO2 remained significantly high for 15 minutes following tourniquet deflation and came to baseline at 20 minutes in GA (ventilation controlled) cases. In spontaneously breathing (regional anaesthesia) patients, EtCO2 remained significantly high for 10 minutes and came to baseline at 15 minutes.

Keywords: Tourniquet, Deflation, EtCO2.

INTRODUCTION

Orthopaedic surgeries of upper and lower limb extremities often require a tourniquet. Tourniquet prevents blood flow to the limb and enables a surgeon to work in a bloodless operative field.[1] This allows surgical procedures to be performed with improved precision, safety and speed.

Effects of Tourniquet Inflation

During inflation, pressure is usually set in tourniquet approximately 100mmhg higher than patients baseline systolic blood pressure. Inflation of tourniquet along with exsanguination causes shifting of blood volume into central circulation. This results in increase in systemic vascular resistance, central venous pressure, mean arterial pressure and heart rate etc. Pressure changes are greater if both the limbs are occluded with tourniquet. These changes are generally benign.

Effects of Tourniquet deflation

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During tourniquet deflation, blood volume is shifted to peripheral circulation which leads to

- Decrease in pH
- Decrease in pO2
- Increase in pCO2
- Increase in K+ and Lactate
- Transient fall in central venous oxygen tension (SvO2)
- Transient increase in etCO2
- Transient fall in core temperature of 0.7C
- Transient fall in central venous and systemic arterial pressures
- Decrease in SBP
- Increase in HR

Acute changes occurring due to tourniquet inflation and deflation may go unnoticed in ASA I & ASA II patients. However they may be detrimental in patients having cardiovascular, neurological, acid base or electrolyte disorders.[2,3] Because tourniquet use may increase the risk of complications like hypertension, hypotension, arrhythmias, nerve inury, compartment syndrome, pressure sores, chemical burns, digital necrosis, deep venous thrombosis leading to pulmonary or venous embolization, tourniquet pain, thermal damage to tissues, and rhabdomyolysis etc.

"Post-tourniquet syndrome" seen in patients,[4] in whom tourniquets applied for prolonged time. The features of this syndrome are swollen, stiff, pale limb with weakness but no paralysis.

Increase in end tidal carbon dioxide (EtCO2) and heart rate, decrease in mean arterial pressure following tourniquet release has been reported in adults as well as in children.[5,6]

These changes can be reduced with minimum duration of tourniquet, monitoring of EtCO2, and controlled ventilation. Monitoring of pulse, BP, ECG, respiratory status, and neurological status are important when the tourniquet is being deflated.

The hemodynamic and metabolic changes depend on tourniquet pressure, the time duration of tourniquet inflation, type of anaesthesia and co-morbidities in the patient.[7]

We planned this observational study to determine the changes occurring in EtCO2 after toutniquet deflation in orthopaedic surgeries and to determine time required for this EtCO2 to come to baseline.

Aim and Objective

1. To determine EtCO2 changes after tourniquet deflation in orthopaedic surgeries.
2. To determine time required for EtCO2 after deflation of tourniquet to return to baseline.

MATERIALS AND METHODS

Study design:

This was a prospective observational study.

Study site:

The present study was conducted in the Department of Anaesthesiology.

Study Population:

This study was conducted in 100 patients. All patients were screened and enrolled on the basis of the study selection criteria. Every enrolled patient was briefed about the purpose of the study and their written, valid, informed consent was taken.

Study duration:

The study was conducted for a period of 2 years.

Study selection criteria

Inclusion criteria

Patients with following criteria were included in the study.

1. Patients belonging to the age group of 18 – 65 years.
2. Patients undergoing elective or emergency upper or lower limb surgery requiring tourniquet.
3. Patients belonging to ASA grade I & II.

Exclusion criteria

Patients with following criteria were excluded from the study:

1. Patients refusing to give consent to participate in the study.
2. Patients belonging to ASA Ill to VI.

Study procedure: The study was initiated only after obtaining approval from the Institutional Ethics Committee of the study site. A written informed consent was obtained from all enrolled patients after explaining in detail the purpose of the study and their role as study participants.

Anaesthesia was given to the included patients (GA, Spinal, Combined spinal and epidural, Regional nerve block) as decided by operation theatre anaesthesiologist.

In general anaesthesia cases, ventilatory parameters were kept constant throughout the study period. All patients were monitored for continuous ECG, heart rate, pulse oximetry, capnography and noninvasive blood pressure. Limb to be operated, was exanguinated by elevating it followed by Esmarch bandage application. Then a pneumatic tourniquet was placed around the proximal part of the limb and inflated to a pressure of 100 mm Hg above systolic blood pressure, and timing of tourniquet inflation was noted. At the end of surgery and 1 minute before the deflation of tourniquet (Pre-release i.e.baseline) EtCO2 was recorded. Then after deflating the tourniquet EtCO2 was recorded at following intervals – 0 minute (just after deflation of tourniquet), then at 1, 5, 10, 15, 20 and 30 minutes following tourniquet release. In intubated patients (GA cases / ventilation controlled), EtCO2 was measured by mainstream capnography method. In spontaneously breathing patients (spinal, combined spinal & epidural & regional nerve block), EtCO2 was measured by modified nasal cannula having sidestream CO2 detector on one side.

Statistical Analysis: The variable EtCO2 is quantitative in nature. It expressed as mean+/-SD and median and range. The differences between baseline and after release of tourniquet were compared by using "analysis of variance (ANOVA)". All analyses had been done at 5% significance. We considered a $P < 0.05$ significant.

RESULTS

A total of 100 patients were enrolled in this study.

1. **Demographic Data**

Table 1: Clinical Data (Mean ± SD).

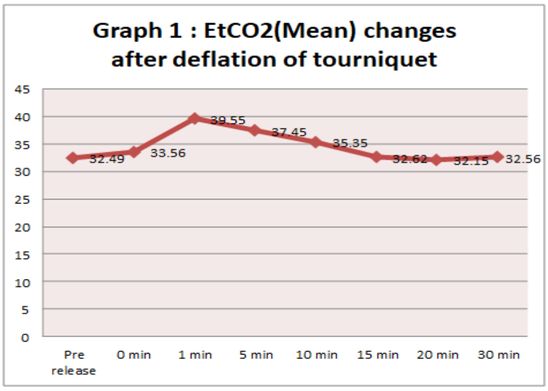
AGE (Years)	36.72 ±13.96
M:F	71:29
ASA I:ASA II	83:17
Upper Limb:Lower Limb	20:80 (1:4)
Tourniquet Time (Minutes)	102.52±21.20
Intraoperative Blood Loss	281.70±158.75

In our study, males were 71% and females were 29%. 83 patients were of ASA I and 17 patients were of ASA II. 80 patients underwent lower limb and 20 patients underwent upper limb surgery. The mean duration of tourniquet application was 102.52±21 minutes with range of 35 to 120 minutes. The mean intraoperative blood loss was 281.70±158.75.

2. EtCO2 Changes After Deflation Of Tourniquet In All Cases

Table 2: EtCO2 Changes (mmHg) after deflation of tourniquet.

Time (Minute)	EtCO2 (Mean±SD)	P value
Pre release	32.49±3.645	
0	33.56±3.828	0.0001
1	39.55±3.261	0.0001
5	37.45±3.307	0.0001
10	35.35±3.307	0.0001
15	32.62±3.398	0.317
20	32.15±3.483	1.000
30	32.56±3.429	0.579

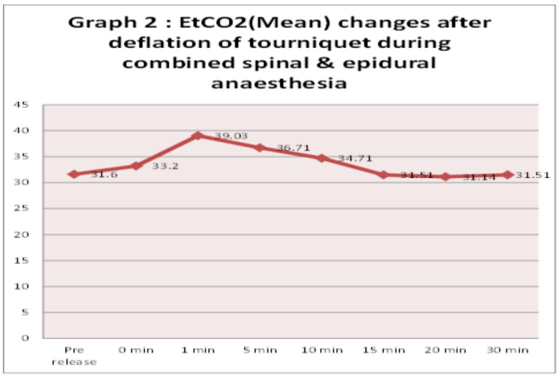


Graph 1 : EtCO2(Mean) changes after deflation of tourniquet

3. EtCO2 Changes During Combined Spinal and Epidural Anaesthesia.

Table 3: ETCO2 Changes (mm Hg) after deflation of tourniquet (Mean±SD) during combined spinal & epidural anaesthesia cases.

Time (Minute)	EtCO2 (Mean±SD)	P value
Pre release	31.60±3.423	
0	33.20±3.669	0.0001
1	39.03±3.120	0.0001
5	36.71±3.348	0.0001
10	34.71±3.195	0.0001
15	31.51±3.372	0.597
20	31.14±3.457	0.287
30	31.51±3.230	0.738

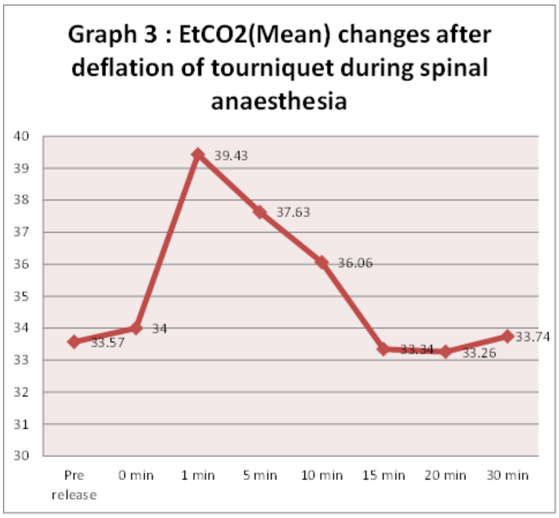


Graph 2 : EtCO2(Mean) changes after deflation of tourniquet during combined spinal & epidural anaesthesia

4. EtCO2 Changes during Spinal Anaesthesia.

Table 4: EtCO2 Changes (mmHg) after deflation of tourniquet (Mean±SD) during spinal anaesthesia cases.

Time (Minutes)	EtCO2 (Mean±SD)	P value
Pre release	33.57±4.104	
0	34.00±4.137	0.002
1	39.43±3.174	0.0001
5	37.63±3.264	0.0001
10	36.06±3.124	0.0001
15	33.34±3.764	0.283
20	33.26±3.567	0.189
30	33.74±3.814	0.362

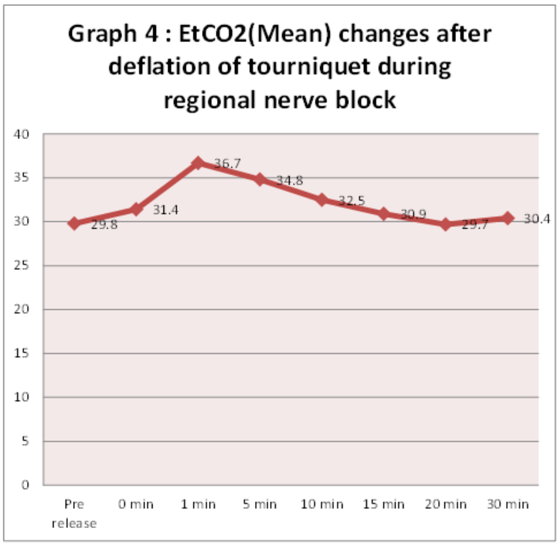


Graph 3 : EtCO2(Mean) changes after deflation of tourniquet during spinal anaesthesia

5. EtCO2 Changes During Regional Nerve Block

Table 5: EtCO2 Changes (mmHg) after deflation of tourniquet (Mean±SD) during regional nerve block.

Time (Minutes)	EtCO2 (Mean±SD)	P value
Pre release	29.80±2.821	
0	31.40±3.373	0.141
1	36.70±2.263	0.0001
5	34.80±2.486	0.0001
10	32.50±2.224	0.008
15	30.90±1.853	0.084
20	29.70±2.359	0.780
30	30.40±2.633	0.140



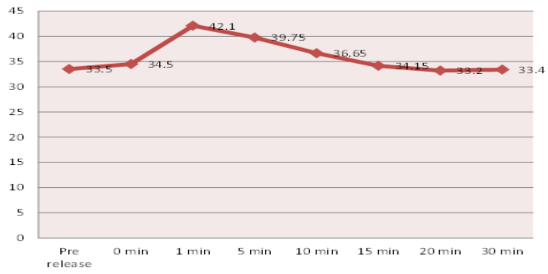
Graph 4 : EtCO2(Mean) changes after deflation of tourniquet during regional nerve block

6. EtCO2 Changes During General Anaesthesia.

Table 6: EtCO2 Changes (mmHg) after deflation of tourniquet (Mean±SD) during GA cases.

Time (Minute)	EtCO2 (Mean±SD)	P value
Pre release	33.50±2.417	
0	34.50±3.502	0.066
1	42.10±2.426	0.0001
5	39.75±2.149	0.0001
10	36.65±2.323	0.0001
15	34.15±2.368	0.039
20	33.20±2.821	0.285
20	33.40±2.348	0.681

Graph 5 : EtCO2(Mean) changes after deflation of tourniquet during GA



EtCO2 values in all tables are expressed as Mean±SD. In above tables , pre release EtCO2 was 32.49±3.645 [Table 2], 31.60±3.423 [Table 3], 33.57±4.104 [Table 4], 29.80±2.821 [Table 5] and 33.50±2.417 [Table 6]. After tourniquet release, the EtCO2 increased to a maximum value at 1 minute in all type of anaesthesia cases as 39.55±3.261 [Table 2], 39.03±3.120 [Table 3], 39.43±3.174 [Table 4], 36.70±2.263 [Table 5], 42.10±2.426 [Table 6]. This difference was statistically significant (p = <0.05) and remained significant till 10 minutes after release of tourniquet in table 2, 3, 4 and 5 (except in table 6). After 10 minutes, EtCO2 reduced and there was no significant difference with pre-release EtCO2 (P= >0.05). EtCO2 returned to baseline value at 15 minutes as 32.62±3.39 [Table 2], 31.51±3.372 [Table 3], 33.34±3.764 [Table 4] and 30.90±1.853 [Table 5] except [Table 6]. In [Table 2-5] P value upto 10 minutes was < 0.05 (significant) and at 15, 20 & 30 minutes was > 0.05 (non-significant).

While in [Table 6] (GA cases), the difference was remained significant till 15 minutes after release of tourniquet. Here EtCO2 returned to baseline value of 33.20±2.821 at 20 minutes. In this table, P value upto 15 minutes was < 0.05 (significant) and at 20 & 30 minutes was > 0.05 (non-significant).

The changes in EtCO2 variable in [Table 2-6] are expressed in [Graphs 1-5] respectively.

DISCUSSION

A total of 100 patients were enrolled in this study. 75% of the patients were 18-45 years of age and 25% were 45-65 years age group. 71% were males and 29% were females. Among males 83% were ASA grade I, 17% were ASA grade II. Among females 26% were ASA grade I, 3% were ASA grade II. 80% surgeries were done on lower limb and 20% were on upper limb. In 10% participants, tourniquet time was < 1 hour & in 90% participants, tourniquet time was between 1 hour -2 hours. The mean ± SD tourniquet time was 102.52 ± 21.20 minutes.

The mean ± SD intraoperative blood loss during surgery was 281.70 ± 158.75.

General anaesthesia, spinal anaesthesia, combined spinal & epidural anaesthesia and regional nerve block given to 20%, 35%, 35% and 10% cases respectively.

Tourniquet is used for bloodless surgeries. Its use is associated with so many changes in the body. Significant systemic effects of tourniquet application appear if it is applied longer than 30 minutes.[8] Changes occurs at biochemical & multisystem level during inflation as well as during deflation of tourniquet.[9] We have only studied end tidal CO2 changes after deflation of tourniquet.

Deflation of tourniquet leads to decrease in pH, pO2 & increase in pCO2 on ABG.

Serum potassium, lactic acid, creatinine kinase & lactic acid dehydrogenase levels also increases after deflation. Transient fall in central venous oxygen tension, core body temperature, central venous pressure, systemic arterial pressure and transient increase in EtCO2, HR occurs after deflation of tourniquet. These changes are usually benign in nature but can be significant in patients with acid base disorders, in pre-existing neurological & cardiovascular diseases.[2,3]

EtCO2 reflects PaCO2 level indirectly. Acute rise in EtCO2 immediately after tourniquet release has been a well established fact. We also observed the same in our study. Rise in end tidal CO2 has deleterious effects on central nervous system. As many times limb trauma may be associated with head injuries, the rise in EtCO2 after tourniquet deflation may be significant.[10] We can avoid a rise in EtCO2 in such surgeries to avoid its deleterious effects on brain.[11]

Akata T et al,[12] reported that 1) the time for EtCO2 level to reach a peak (peak time) was almost constant both in spontaneous breathing and ventilation-controlled groups. The peak time in spontaneous breathing group was shorter than that in ventilation controlled group; and 2) increase in EtCO2 in the spontaneously breathing patients was smaller. Thus, they recommended continuous EtCO2 monitoring and the hyperventilation after tourniquet deflation.

Zaman SM et al showed that when tourniquet was deflated,[13] EtCO2 value increased & the values were maximum at 5 minutes. These values came down to the base line at 15 minutes. These changes are usually benign but may be significant in patients with cardiovascular & neurological diseases. So they recommended EtCO2 monitoring along with hyperventilation for 15-30 minutes after deflation of tourniquet.

Patel AJ et al showed that after deflation of the tourniquet,[14] EtCO2 and PaCO2 reached to peak level within one minute; EtCO2 returned to baseline at a mean time of 13 minutes 7 seconds +/- 5 minutes 17 seconds. The pH, paO2 decreased & bicarbonate increased significantly. So, they recommended monitoring of pH & PaCO2 along with hyperventilation to facilitate the return of pH & PaCO2 to baseline in patients with compromised acid base status.

Dr Mihir P. Pandia et al mentioned the time requiring for the increased EtCO2 to return to baseline.[8] After deflation of tourniquet, peak rise in EtCO2 was seen within one minute. This increased EtCO2 remained high for 10 minutes. This study also recommend hyperventilation in first 10 minutes following release of tourniquet.

Seung Lim Rhee et al showed that significant rise in EtCO2 and PaCO2 was observed after tourniquet deflation.[15] A Peak rise was seen within two minutes. So hyperventilation was advised just before and after tourniquet deflation to facilitate the return of PaCO2 and pH to baseline. They recommend noninvasive monitoring of the EtCO2 level in place of invasive measurement of the PaCO2 level.

Conaty et al found acute rise in EtCO2 after tourniquet deflation.[11] This raised EtCO2 cause increase in cerebral blood flow and increase in intracranial pressure. These things could affect patients of head injury.

Eldrige et al presented a case in which cerebral perfusion pressure significantly decresed due to consequent use of a lower limb tourniquet.[10]

Acute rise in EtCO2 is also detrimental in patients with intracranial pathology with raised intracranial pressure. PaCO2 is one of the important factor which determines cerebral blood flow and intracranial pressure (cerebral blood flow changes about 2 to 4% for each mm Hg changes in PaCO2)

Hirst et al reported a transient increase in cerebral blood flow after tourniquet release.[16]

Chawla et el showed that EtCO2 returned to the predeflation value within 5 minutes. In their study tourniquet was applied for a fixed duration of 30 minutes. In our study tourniquet was applied for longer duration (102.52 ± 21.20). Tourniquet application for such a short period may not produce significant systemic changes.

In our study, we found that EtCO2 level is transiently increased after deflation of tourniquet. A Peak rise in EtCO2 was observed at one minute after deflation of tourniquet in all the cases irrespective of type of anaesthesia. This increased EtCO2 remained high for 15 minutes then started to decrease & came to baseline at 20 minutes in ventilation controlled cases. In spontaneously breathing patients, EtCO2 remained high for 10 minutes then started to decrease & came to baseline at 15 minutes. Thus EtCO2 came to baseline early in spontaneously breathing patients. This might be because of compensatory ability of spontaneously breathing patients. The patients with controlled mechanical ventilation unable to alter their ventilatory rate. We recommend hyperventilation for 15-20 minutes after deflation of tourniquet.

Limitations

1) We did not compare the changes in EtCO2 with tourniquet time and intra operative blood loss.
2) We did not compare the changes in EtCO2 with different types of anaesthesia.
3) We did not compare the changes in EtCO2 in upper limb with lower limb surgeries.

CONCLUSION

After analyzing this study, the following conclusions were made

1. There was a peak rise in EtCO2 at one minute in all type of anaesthesia cases.
2. EtCO2 remained significantly high for 15 minutes following tourniquet deflation and came to baseline at 20 minutes in GA (ventilation controlled) cases.
3. In spontaneously breathing (regional anaesthesia) patients, EtCO2 remained significantly high for 10 minutes and came to baseline at 15 minutes.
4. EtCO2 returned to baseline early in spontaneous breathing patients than GA (ventilation controlled).

So, we recommend hyperventilation for 20 minutes following tourniquet deflation in high risk patients to prevent deleterious effects of raised EtCO2.

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