International Journal of Current Advanced Research
ISSN: O: 2319-6475, ISSN: P: 2319-6505, Impact Factor: SJIF: 5.995
Available Online at www.journalijcar.org
Volume 6; Issue 12; December 2017; Page No. 8192-8197
DOI: http://dx.doi.org/10.24327/ijcar.2017.8197.1308

Research Article

ASSESSMENT OF HEMODYNAMIC PARAMETERS AFTER RELEASE OF TOURNIQUET IN ORTHOPAEDIC SURGERIES

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A R T I C L E I N F O

Article History:
Received 11th September, 2017
Received in revised form 25th October, 2017
Accepted 14th November, 2017
Published online 28th December, 2017

Key words:
Tourniquet, Deflation, MAP, HR.

A B S T R A C T

With the help of tourniquet, surgeon can work in bloodless operative field. Many changes occure after release of tourniquet. This observational study was planned to assess the changes occurring in hemodynamic parameters (MAP, HR) after release of toutniquet in orthopaedic surgeries.
100 patients of ASA grade I & II, 18 – 65 years of age, posted for orthopaedic surgeries using tourniquet were selected for the study. When surgery was over, pre releaseheart rate(HR) and mean arteria l pressure(MAP) were recorded. Then tourniquet was released and MAP &HR were recorded at following intervals – 0 minute (just after release of tourniquet), 1, 5, 10, 15, 20 and 30 minutes.
Significant fall in MAP was observed till 15 minutes with peak fall at 5 minutes after tourniquet release. Peak rise in HR was observed at 1 minute which remained high for 10 minutes after release of tourniquet.

INTRODUCTION

A tourniquet is a device which is used to control the blood flow to and from an extremity(Sharma JP *et al,* 2012). Tourniquets prevent blood flow to a limb. So surgeons can work in a bloodless operative field (Kumar K *et al,* 2016). Tourniquets are used in orthopedic surgery, plastic surgery & in intravenous regional anesthesia (Bier block anesthesia) as they prevent local anesthetic in the limb from entering in circulation. In emergency, tourniquets are used for bleeding control to prevent severe blood loss from limb injury.

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. (Dickson M *et al,* 1990; Brustowicz RM *et al,* 1987). Acute changes in these parameters may be detrimental in patients having cardiovascular, intracranial, acid base or electrolyte disorders. (Valli H *et al,* 1985; Tsuchiya M *et al,* 1991).

During inflation, blood volume is rapidly shifted in central circulation which leads to gradually increase of central venous pressure, mean arterial pressure and heart rate etc.

During tourniquet deflation, blood volume is shifted to peripheral circulation which leads to decrese in central venous pressure, mean arterial pressure & increase in heart rate.

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The hemodynamic and metabolic changes depend on tourniquet pressure, the time duration of tourniquet inflation, type of anaesthesia and co-morbidities in the patient. (Budic I *et al,* 2010) We planned this observational study to determine the changes occurring in hemodynamics after toutniquet release in orthopaedic surgeries and to determine time required for these parameters to come to baseline.

Complications of tourniquet

Most common complication is nerve injury.(Van der *et al,* 2012) Intraoperative bleeding may occur due to an under-pressurized cuff, insufficient exsanguination, improper size of cuff, loose application of cuff, calcification of vessels or too slow inflation or deflation Other complcations are 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.

Contraindications

Relative contraindications to tourniquet use are severe infection of limbs, poor cardiac reserve patients, and traumatized limbs, peripheral neuropathy & peripheral vascular disease. Tourniquets can be use in patients with sickle cell disease and trait. (Fisher B *et al,* 2010)

Aims and Objectives

1. To assess changes in hemodynamics (MAP, HR) after release of tourniquet in orthopaedic surgeries.

2. To find out time for hemodynamics (MAP, HR) to return to baseline after release of tourniquet in orthopaedic surgeries.

MATERIALS AND METHODS

This prospective observational study was conducted in the department of anaesthesiology for a period of 2 years after obtaining permission from the Institutional Ethics Committee. Written informed consent was obtained from all the patients. 100 patients of ASA grade I & II, 18 – 65 years of age, posted for orthopaedic surgeries using tourniquet were selected for the study

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 release of tourniquet (pre release i.e.baseline) heart rate and mean arterial pressure were recorded. Then after releasing the tourniquet MAP, Heart rate were recorded at following intervals – 0 minute (just after release of tourniquet), then at 1, 5, 10, 15, 20 and 30 minutes following tourniquet release. MAP & heart rate were measured by noninvasive blood pressure technique and ECG in all the cases respectively.

Statistical Analysis

The variables heart rate and mean arterial pressure are quantitative in nature. They were 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.

Demographic Data

Table 8 Clinical Data (Mean±SD)

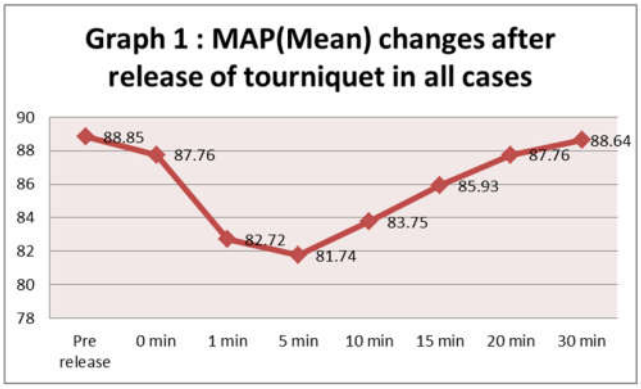
AGE(Years)	36.72 ±13.96
M:F	71:29
ASA I:ASA II	83:17
Upper limb:lower limb	20:80(1:4)
Tourniquet time(minutes)	102.52±21.20
Intraoperative blood loss	281.70±158.75

In our study, 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.

Mean Arterial Pressure Changes After Release Of Tourniquet In All Cases

Table 2 MAP (mmHg) changes after release of tourniquet in all cases

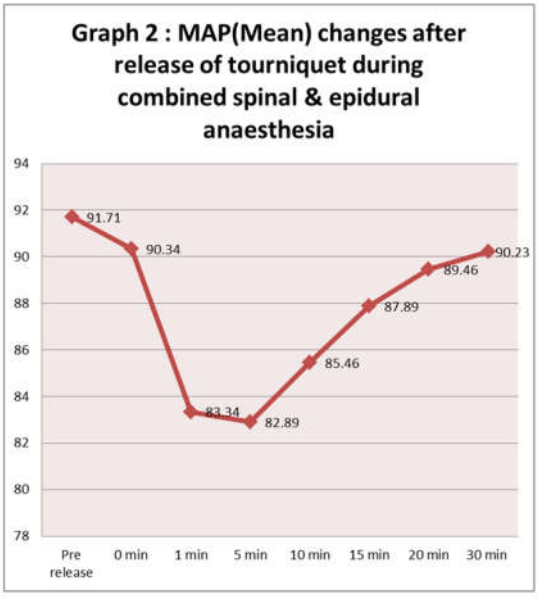
Time(Minute)	MAP(Mean±SD)	P Value
PRE RELEASE	**88.85±8.198**	
0 MIN	87.76±8.174	0.0001
1 MIN	82.72±7.762	0.0001
5 MIN	81.74±8.136	0.0001
1O MIN	83.75±8.086	0.0001
15 MIN	85.93±7.985	0.0001
20 MIN	87.76±7.980	0.062
30 MIN	88.64±7.843	1.000



MAP Changes During Combined Spinal And Epidural Anaesthesia

Table 3 MAP Changes (mm Hg) after release of tourniquet (Mean±SD) during combined spinal & epidural anaesthesia

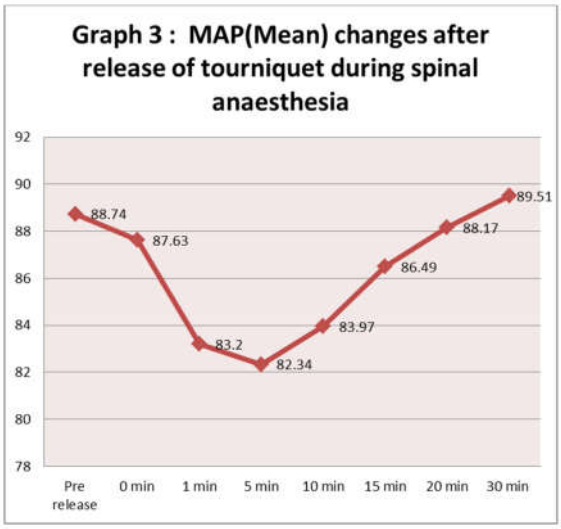
Time(Minute)	MAP(Mean±SD)	P value
Pre release	91.71±7.610	
0	90.34±7.608	0.0001
1	83.34±7.104	0.0001
5	82.89±7.794	0.0001
10	85.46±7.931	0.001
15	87.89±7.787	0.039
20	89.46±7.743	0.163
30	90.23±7.499	0.836



Map Changes during Spinal Anaesthesia

Table 4 MAP Changes (mmHg) after release of tourniquet (Mean±SD) during spinal anaesthesia cases

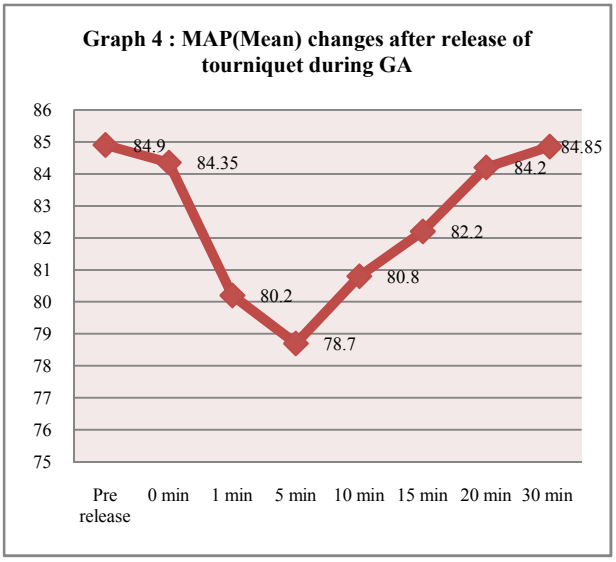
Time(Minutes)	MAP(Mean±SD)	P value
Pre release	88.74±9.176	
0	87.63±9.085	0.0001
1	83.20±8.844	0.0001
5	82.34±9.120	0.0001
10	83.97±9.389	0.0001
15	86.49±9.182	0.0001
20	88.17±8.939	0.343
30	89.51±8.569	0.166



Map Changes During General Anaesthesia

Table 5 MAP Changes (mmHg) after release of tourniquet (Mean±SD) during GA

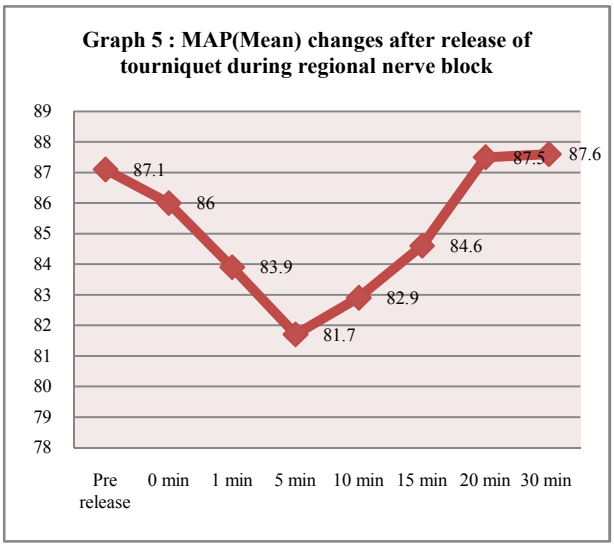
Time(Minute)	MAP(Mean±SD)	P value
Pre release	**84.90±6.390**	
0	84.35±6.620	0.061
1	80.20±7.083	0.0001
5	78.70±7.248	0.0001
10	80.80±6.066	0.0001
15	82.20±5.597	0.0001
20	84.20±5.718	0.337
30	84.85±5.761	0.944



MAP Changes during Regional Nerve Block

Table 6 MAP Changes (mmHg) after release of tourniquet (Mean±SD) during regional nerve block

Time(Minutes)	MAP(Mean±SD)	P value
Pre release	87.10±6.790	
0	86.00±7.528	0.075
1	83.90±7.249	0.0001
5	81.70±6.816	0.0001
10	82.90±6.262	0.0001
15	84.60±6.221	0.0001
20	87.50±7.934	0.522
30	87.60±8.409	0.544

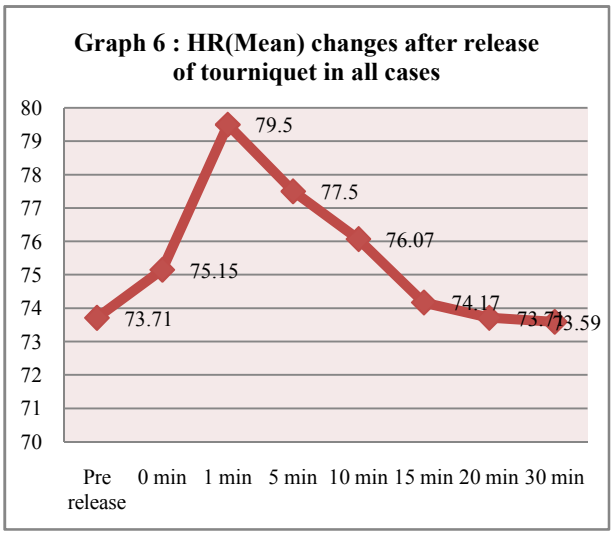


MAP values in tables 2, 3, 4, 5 & 6 are expressed as Mean±SD. P value upto 15 minutes was < 0.05 (significant) and at 20 & 30 minutes was > 0.05 (non-significant). In above tables, pre release MAP was 88.85±8.198 (table 2), 91.71±7.610(table 3), 88.74±9.176(table 4), 84.90±6.390(table 5) and 87.10±6.790(table 6). After tourniquet release, the MAP decreased to a minimum value at 5 minutes as 81.74±8.136 (table 2), 82.89±7.794 (table 3), 82.34±9.120 (table 4), 78.70±7.248(table 5) and 81.70±6.816 (table 6). This difference was statistically significant (p = <0.05) and remained significant till 15 minutes after release of tourniquet. After 15 minutes, MAP increased and there was no significant difference with pre-release MAP (P= >0.05) Finally, MAP returned to baseline value at 20 minutes as 87.76±7.980(table 2), 89.46±7.743(table 3), 88.17±8.939(table 4), 84.20±5.718(table 5) and 87.50±7.934 (table 6). MAP changes in tables 2, 3, 4, 5 & 6 are expressed in graphs 1, 2, 3, 4 & 5 respectively.

Heart Rate Changes after Release of Tourniquet in All Cases

Table 7 Heart rate (per minute) changes after release of tourniquet in all cases

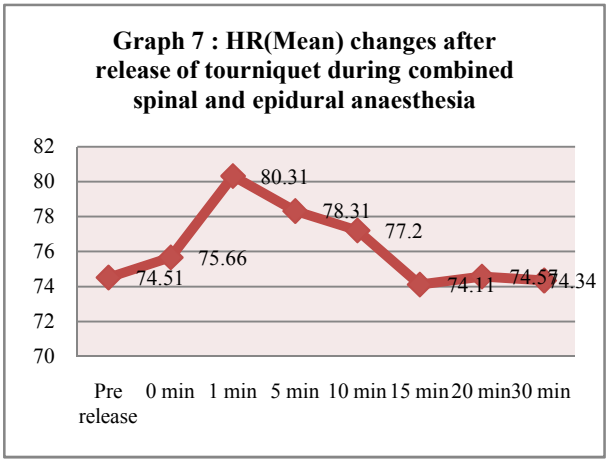
Time	HR(Mean±SD)	P Value
PRE RELEASE	**73.71±9.782**	
0 MIN	75.15±10.123	0.0001
1 MIN	79.50±10.804	0.0001
5 MIN	77.50±10.818	0.0001
10 MIN	76.07±9.970	0.0001
15 MIN	74.17±9.605	1.000
20 MIN	73.71±9.707	1.000
30 MIN	73.59±10.028	0.604



HR Changes During Combined Spinal and Epidural Anaesthesia

Table 8 HR Changes after release of tourniquet (Mean±SD) during combined spinal & epidural anaesthesia

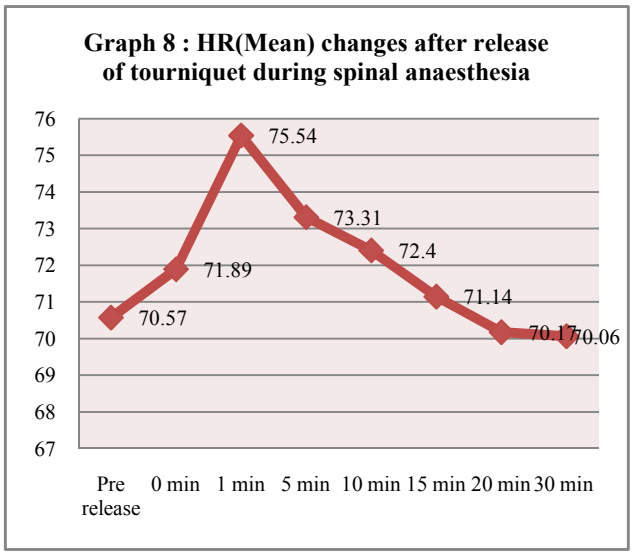
Time(Minute)	HR (Mean±SD)	P value
Pre release	74.51±9.762	
0	75.66±9.997	0.0001
1	80.31±11.517	0.0001
5	78.31±10.734	0.0001
10	77.20±9.130	0.0001
15	74.11±8.927	0.366
20	74.57±9.378	0.846
30	74.34±9.609	0.617



HR Changes during Spinal Anaesthesia

Table 9 HR Changes after release of tourniquet (Mean±SD) during spinal anaesthesia

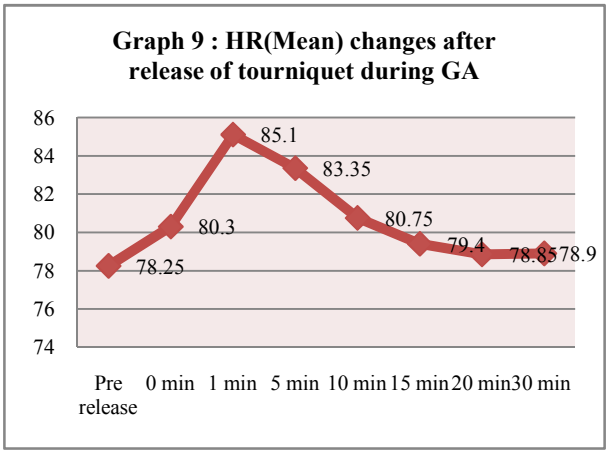
Time(Minute)	HR(Mean±SD)	P value
Pre release	70.57±9.469	
0	71.89±9.361	0.007
1	75.54±9.128	0.0001
5	73.31±9.967	0.0001
10	72.40±9.870	0.0001
15	71.14±9.933	0.106
20	70.17±9.417	0.346
30	70.06±9.283	0.203



HR Changes during General Anaesthesia

Table 10 HR Changes after release of tourniquet (Mean±SD) during GA

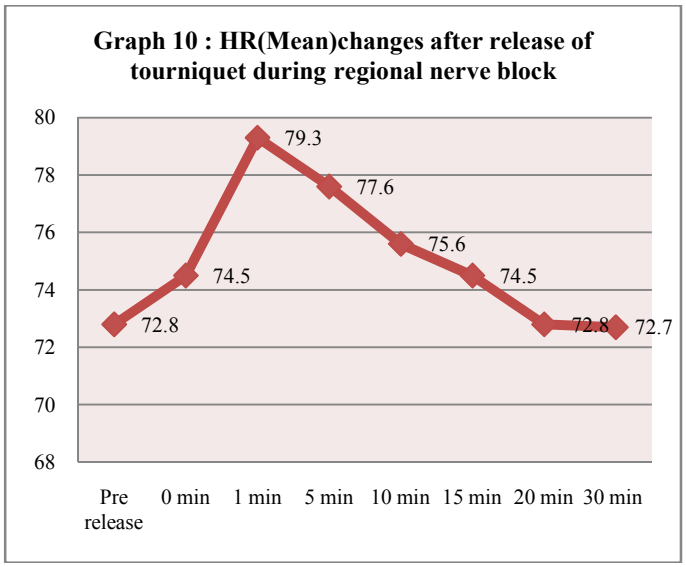
Time(Minute)	HR(Mean±SD)	P value
Pre release	78.25±10.073	
0	80.30±10.993	0.0001
1	85.10±11.092	0.0001
5	83.35±10.994	0.0001
10	80.75±10.676	0.0001
15	79.40±9.361	0.102
20	78.85±9.869	0.235
30	78.90±11.374	0.302



HR Changes During Regional Nerve Block

Table 11 HR Changes after release of tourniquet (Mean±SD) during regional nerve block

Time(Minute)	HR(Mean±SD)	P value
Pre release	72.80±7.208	
0	74.50±7.849	0.035
1	79.30±8.667	0.0001
5	77.60±8.644	0.001
10	75.60±7.989	0.012
15	74.50±7.721	0.101
20	72.80±7.239	1.000
30	72.70±6.667	0.888



Heart rate values in tables 7, 8, 9, 10 & 11 are expressed as Mean±SD. P value upto 10 minutes was < 0.05 (significant) and at 15, 20 & 30 minutes was > 0.05 (non-significant). In table 7, 8, 9, 10 & 11, pre release HR was 73.71±9.782 (table 7), 74.51±9.762 (table 8), 70.57±9.469 (table 9), 78.25±10.073 (table 10) & 72.80±7.208 (table 11),. After tourniquet release, the HR increased to a maximum value at 1 minute as 79.50±10.804 (table 7), 80.31±11.517 (table 8), 75.54±9.128 (table 9), 85.10±11.092 (table 10) & 79.30±8.667(table 11). This difference was statistically significant (p = <0.05) and remained significant till 10 minutes after release of tourniquet. After 10 minutes, HR reduced and there was no significant difference with pre-release HR (P= >0.05). Finally HR returned to baseline value at 15 minutes as 74.17±9.605(table 7), 74.11±8.927(table 8), 71.14±9.933(table 9), 79.40±9.361(table 10) & 74.50±7.721(table 11). The HR changes in tables 7, 8, 9, 10 & 11 are expressed in graphs 6, 7, 8, 9 & 10 respectively.

DISCUSSION

A total of 100 patients were enrolled in this study.
General anaesthesia, spinal anaesthesia, combined spinal & epidural anaesthesia and regional nerve block given to 20%, 35%, 35% and 10% cases respectively.

Tourniquet use is associated with so many changes in the body. Changes occurs at biochemical & multisystem level during inflation as well as during deflation of tourniquet (Modig J *et al,* 1978). We have assess only changes in hemodynamic parameters (heart rate, mean arterial pressure) after release of tourniquet.

Mean Arterial Pressure Changes

We observed that after release of tourniquet, mean arterial pressure decreased significantly. This is due to redistribution of blood volume to the peripheral circulation (Samii K *et al,* 1979). A post ischaemic reactive hyperemia (vasodilatation) and a decrease in peripheral vascular resistance may be responsible for decrease in blood pressure (Modig J *et al,* 1978)
Zaman SM (Zaman SM *et al,* 2010) *et al* showed that mean arterial pressure (MAP) decreased significantly at 5 minutes; and came to the baseline at 15 minutes. Hemodynamic monitoring with rapid fluid administration for 15-30 minutes after release of tourniquet is recommended by this study.

Dr Mihir P.Pandia (Pandia MP *et al,* 2003) mentioned significant fall in blood pressure after tourniquet release in their study .This fall in blood pressure persisted for 5 minutes. This study also recommended fast intravenous fluids administration in the first 10 minutes after tourniquet deflation. Akata T (Akata T *et al,* 1992) *et al* also found decrease in blood pressure after tourniquet deflation in their study. But they have not mentioned that upto what time MAP remained low and at what time it came to baseline level.

In Inkyung Song (Song I *et al,* 2012) study, significant decrease in MAP found in 2-12 minutes following deflation of tourniquet. Their study found no relationship between maximal decrease of MAP and regional cerebral oxygen saturation. Significant changes in hemodynamic and metabolic status were noted but not in regional cerebral oxygen saturation. Therefore according to this study, monitoring of neurologic as well as hemodynamic and metabolic status is important to avoid serious complications, especially in elderly patients.

Sharrock N (Sharrock *et al,* 2006) observed fall in MAP after deflation of tourniquet. In this study, they also found that changes in MAP after tourniquet deflation did not correlate with the duration of tourniquet inflation time.

In Kahn (Kahn RL *et al,* 1992) *et al* study on hemodynamic changes associated with tourniquet use, reduction in mean arterial pressure was found after deflation of tourniquet. Fall in MAP upto 19.2 +/- 12% occurred within one minute.

In our study, reduction in MAP also observed after release of tourniquet in all cases irrespective of type of anaesthesia.. Signiflcant fall in MAP was found at 5 minutes. MAP remained low for 15 minutes (p=<0.0001) then started to increase & came to baseline level at 20 minutes (p=>0.062) after release of tourniquet..

Mean arterial pressure is another important factor which determine the cerebral tissue blood supply. It is recommended that a minimum of 70 mmHg of cerebral perfusion pressure should be maintained to prevent secondary ischaemic insult in head injured patients (Changaris DG *et al,* 1987).

Eldrige (Eldridge PR *et al,* 1989) *et al* reported a sudden decrease of cerebral perfusion pressure from 65 mmHg to 50 mmHg with release of tourniquet. In head injury patients posted for orthopaedic surgeries under tourniquet application, haemodynamic changes occuring after release of tourniquet may further aggravate the cerebral damage. We recommend fast administration of intravenous fluids in first 20 minutes after release of tourniquet.

Heart Rate Changes

We observed that after release of tourniquet, heart rate increased significantly in all cases.

Akata T (Akata T *et al,* 1992) *et al* study on tourniquet deflation mentioned that heart rate increased after tourniquet deflation. But their study did not mention about time till HR remained high and at what time it returned to baseline. According to Zaman SM (Zaman SM *et al,* 2010) *et al*, heart rate increased after release of tourniquet. HR value was maximum at 5 minutes and remained high for 10 minutes. It returned to baseline at 15 minutes.

In our study, heart rate also increased after release of tourniquet. Significant rise in HR was found at 1 minute. HR was remained high for 10 minutes (p=<0.0001) & came to baseline level at 15 minutes after release of tourniquet irrespective of type of anaesthesia. (p=>1.000)

Limitations

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

CONCLUSION

a. Significant fall in mean arterial pressure was observed till 15 minutes with peak fall at 5 minutes and returned to baseline at 20 minutes after deflation of tourniquet irrespective of type of anaesthesia.
b. Peak rise in heart rate was observed at one minute and it remained high for 10 minutes after deflation of tourniquet. It returned to baseline at 15 minutes in all cases irrespective of type of anaesthesia.

We recommend fast intravenous fluid administration for 20 minutes following tourniquet deflation.

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How to cite this article:

Salman Tadavi *et al* (2017) 'Assessment of Hemodynamic Parameters After Release of Tourniquet in Orthopaedic Surgeries ', *International Journal of Current Advanced Research,* 06(12), pp. 8192-8197.
DOI: http://dx.doi.org/10.24327/ijcar.2017.8197.1308

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