B-mode and Doppler ultrasonography of cranial epigastric vein in healthy and diseased cows and buffaloes

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ABSTRACT

The study was aimed to examine the right cranial epigastric vein (CEV) using B-mode and Doppler ultrasonography in clinically healthy non-gravid cows (20) and buffaloes (20); bovines suffering from traumatic reticuloperitonitis (15 cows and 20 buffaloes) and reticulo-diaphragmatic hernia (5 cows and 15 buffaloes). The data was statistically analyzed and compared between and within the groups. The Doppler parameters of cranial epigastric vein in healthy bovines showed a significant species difference. The blood flow velocities, peak systole (PS), end diastole (ED), time average maximum (TA max) and time average mean (TA mean) were significantly higher in cows compared to buffaloes. However, the pulsatility index (PI), the resistive index (RI), vessel diameter and the depth of the vein were significantly higher in buffaloes compared to cows. The highest per cent change in the Doppler parameters of cranial epigastric vein in between the healthy cows and buffaloes were recorded in the PI followed by the RI. A significant decrease in PS, ED, TA max, TA mean and blood volume flow/min was recorded in cows suffering from traumatic reticuloperitonitis (TRP) and reticulo-diaphragmatic hernia (RDH). The reduction was more in cows with RDH compared to TRP. The CEV was significantly more superficial in TRP affected cows. The PI of TRP affected cows and the TA mean of RDH affected cows recorded the highest per cent change compared to healthy cows. In buffaloes, only the PS was significantly increased in TRP affected buffaloes and those suffering from RDH. Significant species-specific differences exist in the blood flow parameters of healthy cows and buffaloes. Doppler blood flow parameters of diseased cows suffering from TRP and RDH was more significantly affected compared to that of buffaloes. The database generated for non-gravid crossbred Indian cows and buffaloes can be used as a reference range for further studies.

Key words: Bovines, Cranial epigastric vein, Diaphragmatic hernia, Traumatic reticuloperitonitis, Ultrasound

In ruminants, the milk vein courses cranially and passes through the abdominal wall to join the cranial epigastric or the internal thoracic vein, bilaterally. While passing through the diaphragm, it is joined by the musculophrenic vein from the lateral side and forms the internal thoracic vein which further drains into the subclavian vein. The subclavian vein on joining the external jugular vein forms the cranial vena cava and enters the heart (Pasquini *et al.* 2003). The cranial epigastric vein (CEV), as the name suggests passes below the gastric region, on the abdominal side of the rectus abdominus muscle.

While scanning of the reticulum from the ventral side and moving parallel and lateral to sternum, CEV is prominently seen ventral to the reticulum. Earlier reports on the Doppler study of a similar vessel in this region, quoted as musculophrenic vein, are available in normal healthy cattle and its comparison with milk vein of cows

having different levels of milk yield (Braun and Gotz 1994, Braun *et al.* 2009, Braun *et al.* 2013, Braun and Forster 2012).

The CEV is the continuation of the milk vein as it enters the rectus abdominus muscle through the milk well (Pasquini *et al.* 2003). The blood supply to the fore-stomach in ruminants is from the celiac artery/vein and there is no direct involvement of cranial epigastric vein or musculophrenic vein in the drainage of blood coming from the fore-stomach in ruminants. But, pressure of the rumen due to stasis or as a sequel to foreign body syndrome might affect the blood supply of musculophrenic vein (Braun *et al.* 2009) or cranial epigastric vein in cattle.

B-mode or Doppler study of CEV on clinically healthy buffaloes and cows had not been reported so far. Since, cows and buffaloes are two different species and show variation in the basic clinical parameters as well as elasticity and thickness of muscles and skin, hence there might be some species difference in the B-mode and Doppler blood flow patterns of this vein which will represent the ultrasonographic anatomy and physiology of this vein in live bovines. The study also intended to find out if the B-

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mode or Doppler parameters of CEV are affected in fore-stomach disease conditions like traumatic reticulo-peritonitis (TRP) and reticulo-diaphragmatic hernia (RDH). Since, the vein is always seen ventral to reticulum form both sides and these 2 abnormalities are the commonest of fore-stomach in Indian conditions, hence the study was planned to evaluate right CEV of clinically healthy non-gravid cows and buffaloes using B-mode and Doppler ultrasonography and create a database for future reference; statistically compare the B-mode and Doppler blood flow parameters of right CEV in clinically healthy non-gravid cows and buffaloes, clinically healthy and diseased (TRP affected and RDH affected) non-gravid buffaloes and in clinically healthy and diseased (TRP affected and RDH affected) non-gravid cows.

MATERIALS AND METHODS

The present study was duly approved by the Institutional Animal Ethics Committee. Cranial epigastric vein in 95 bovines was scanned by Doppler ultrasonography. Out of 95, 40 were healthy non-gravid bovines [20 cows (Group 1) and 20 buffaloes (Group 2)] and remaining 55 were diseased [15 cows (Group 3) and 20 buffaloes (Group 4) suffering from traumatic reticulitis (TRP), and 5 cows (Group 5) and 15 buffaloes (Group 6) suffering from reticulo-diaphgramatic hernia (RDH)]. The diseased bovines were diagnosed for traumatic reticulitis (TR) based on the presence of potential foreign body on lateral reticular radiograph (Makhdoomi *et al.* 2018) with no reticular reaction on ultrasonography; traumatic reticulo-peritonitis (TRP) with presence of associated peritonitis on ultrasonography along with potential foreign body on radiograph; and RDH positive based on the radiography and or ultrasonography (Mohindroo *et al.* 2007, Saini *et al.* 2007, Kumar *et al.* 2017).

Apart from the 40 clinically healthy bovines, four adult bovines (2 cows and 2 buffaloes) euthanized for untreatable fractures were used to study the course of cranial epigastric vein. Immediately after euthanasia of such bovines, a catheter was passed into the milk vein by giving a stab incision caudal to milk well. The catheter was moved cranially until it stopped moving. These bovines were than examined during postmortem, to trace the course of the vessel and the findings were recorded.

For B-mode and Doppler ultrasound scanning in all the bovines, one square feet area behind the right elbow, from the sternum to laterally was prepared by clipping hair. The bovines were restrained in standing position, in a cattle crate with head tied. A 2-5 or 7–12 MHz (depending on the depth of the vessel or colour flow), multi-frequency convex transducer on Wipro Logiq 3 expert ultrasound machine with in-built function for colour flow and pulsed wave Doppler was used to scan the reticulum and the CEV in all the groups.

Colour Doppler ultrasonography of CEV was done in all the bovines from right side using pulsed wave function of the machine. The angle of incidence was kept at 60º and

other parameters such as gain, sample volume and pulse repetition frequency (PRF) were set as required for each animal. A mean of three values of Doppler was taken for each vessel for statistical analysis.

Scanning of the cranial epigastric vein in bovines: The right cranial epigastric vein was examined at the level of 6–7 rib, on the right lateral aspect of the sternum, where the reticulum was visible. The transducer was held parallel to the longitudinal axis of the animal body, directed slightly outward (Fig. 1). Reticular and rumen wall was invariably seen moving, when the CEV was viewed in bovines. The transducer was fixed in longitudinal section on the vein corresponding to reticular wall and colour flow mode was switched on to visualize the proper flow of blood within the vessel lumen. Gain adjustments were made to minimize aliasing. The MD cursor (the reference line where M-mode or Doppler is desired) was placed at the site where pulse Doppler was desired. When the flow was smooth and constant, the pulse wave mode was switched on. The sample volume and PRF were set as per the vessel diameter and flow pattern, respectively. Variables of Doppler study,

Fig. 1. Localization of CEV in a cow.

including peak systole (PS) (cm/s), end diastole (ED) (cm/s), TA Max (cm/s), pulsatility index (PI), resistive index (RI), and TA Mean (cm/s) were automatically determined by the machine software upon freezing the Doppler image. The diameter of the vessel, from the intima to the intima, and the distance of the vessel from the transducer were determined using the in-built electronic caliper and at the site of Doppler, i.e. where the reticulum was visible along with the CEV. The diameter of the vessel was further used by the machine software to calculate volume flow (ml/min).

Statistical analysis: The statistical analysis was done using SPSS 16.0 software, at 1% and 5% level of significance (p). The mean and standard deviation (SD) of all the parameters, in all the groups were calculated. Bivariate 2-tailed Pearson correlation coefficient (r) was calculated to assess correlation between basic parameters like age, weight, vessel diameter, volume flow and distance of the vessel from the transducer in CEV for all the groups. The vessel diameter, volume flow and the depth of the vessel

from the transducer were also correlated with the main Doppler variables (PS, ED, PI and RI). Statistical differences in the blood flow parameters of the CEV between Group 1 and Group 2; Group 1 and 3; Group 1 and 5; Group 2 and 4; Group 2 and 6 was tested using 2-tailed Student's t-test. The per cent change between the Doppler variables showing significant differences between the groups was also calculated.

RESULTS AND DISCUSSION

Localization and identification of healthy CEV on post-mortem examination: On post-mortem examination of four bovines (2 cattle and 2 buffalo), the milk vein was found to be continuing into the cranial epigastric vein on the ventral aspect of the reticulum. The CEV was seen on the abdominal side of the rectus abdominus muscle on post-mortem (Fig. 2). The musculophrenic vein coming from the dorso-caudal direction joined the cranial epigastric vein at 5th rib in all the bovines studied (Fig. 3). After uniting with the musculophrenic vein, the CEV was not traced, as it entered the thoracic cavity, as an internal thoracic vein. While dissecting the CEV, the opening of musculo-phrenic vein
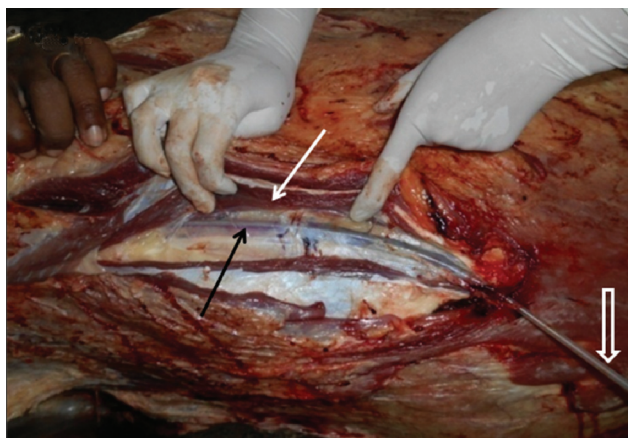

Fig. 2. Milk vein (hollow white arrow) continuing into the CEV (black arrow) on the rects abdominus muscle (white arrow).
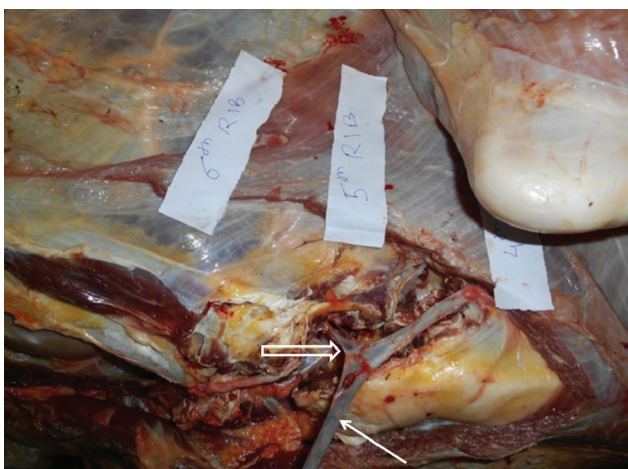

Fig. 3. Musculophrenic vein (hollow white arrow) joining the CEV (white arrow) at 5th rib-ICS on post-mortem.

could be seen into the cranial epigastric vein. At this point, the diameter of CEV was highest with an average of 1.35 cm and 1.45 cm, while the average diameter of musculophrenic vein was 0.35 cm and 0.45 cm in cows and buffaloes, respectively.

B-mode and Doppler ultrasound findings of CEV in Group 1: The 20 cows scanned in Group 1 had a mean±SD body weight of 397.35±51.16 kg (325 to 500 kg) and were aged 5.3±1.86 years (range 2–10 years). In adult cows, the CEV was identified on both sides, cranio-medial to the milk well into the rectus musculature. The CEV was easily differentiated from the milk vein on B-mode and colour flow ultrasound as the milk vein was seen lying in the sub-cutaneous tissue while, the CEV was seen dorsal to the rectus abdominus muscle. The diameter of milk vein decreased once it entered the rectus abdominus muscle and became cranial epigastric vein, but its depth and diameter increased as it coursed cranially. The CEV was scanned upto a level of 6th or 7th rib before entering the thoracic cavity. CEV was invariably seen while scanning reticulum from the ventro lateral aspect. The values of B-mode and Doppler ultrasound for CEV were taken at the site where the reticular wall was visible. The union of CEV with the musculophrenic vein was not visualized in all the cows studied. Occasional valves were also visible in the vein (Fig. 4).
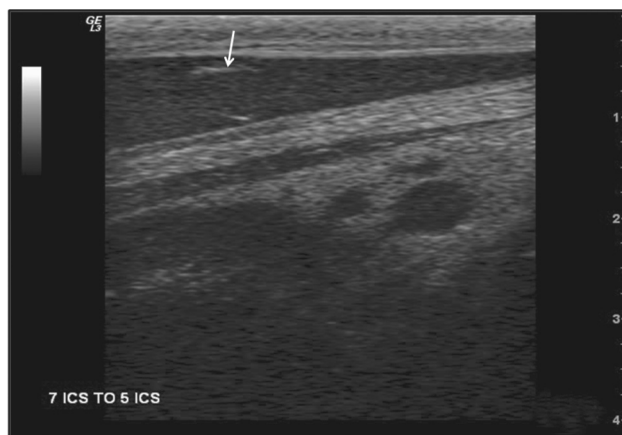

Fig. 4. B-mode scan showing non-uniform diameter of CEV with valves (white arrow) as it enters abdominal musculature from the milk well.

In cows, the vein was stable, but the diameter of the vein was affected with the pressure of the transducer on the rectus abdominus muscle, and the movement of diaphragm. Superficial veins like jugular and milk vein are collapsible structure and their diameter varies significantly with the application of pressure, as reported in cattle and buffaloes (Braun *et al.* 1994, Braun and Fohn 2005, Braun *et al.* 2009, Sangwan *et al.* 2015). The diaphragmatic muscle was visualized on the abdominal side of the CEV. Reticular movements were not seen to be affecting the vessel diameter or position in healthy cows. The localization and Doppler scanning of cranial epigastric vein in cows and buffaloes was easy compared to that of jugular vein (Braun *et al.*

2009, Sangwan *et al.* 2015) as it was well tolerated by the animal.

The CEV had a wind blow like sound and the spectral display varied from broad band with a wave like course in most of the cows to a smooth broad band in few (Fig. 5). The CEV was scanned at a depth of 2.29±0.38 cm (range 1.66–2.94 cm) from the body surface, and had a mean±SD diameter of 0.61±0.15 cm (range 0.41–1.05 cm) at the level of 6–7th rib. The diameter and depth of the CEV in the present study corroborates with the diameter of musculophrenic vein reported by Braun *et al.* (2009).
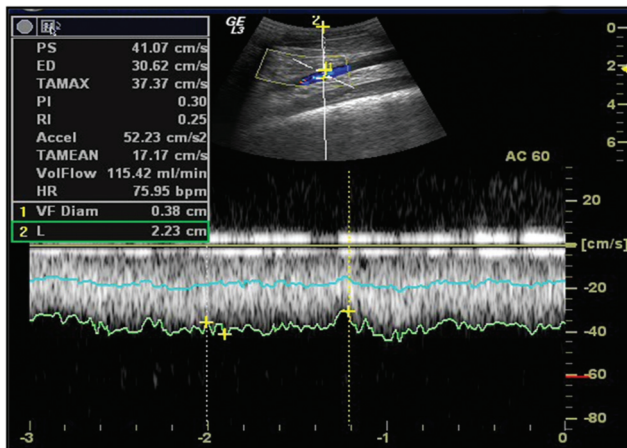

Fig. 5. Doppler scan of CEV in a healthy cow.

A significant positive correlation (r=0.678, p=0.001) existed between the vessel diameter and the volume flow of blood in the CEV of cows. There were also significant positive correlations between the volume flow/min and the velocities; PS (r=0.751, P<0.001), ED (r=0.874, P<0.001), TA max (r=0.843, P<0.001), TA mean (r=0.861, P<0.001). The vessel diameter however, had a significant negative correlation (r=–0.579, p=0.008) with the RI of the vessel.

B-mode and Doppler ultrasound findings of CEV in Group 2: The 20 buffaloes scanned in Group 2 had a mean±SD body weight of 496.05±85.62 kg (370 to 685 kg) and were aged 6.73±2.96 years (range 3.5 to 15 years). The identification and B-mode findings in Group 2 were similar to that in Group 1. The Doppler scan and proper visualization of CEV in buffaloes required moderate pressure on the transducer, which otherwise was not in cows. As in cows, the reticular movements were not seen to be affecting the vessel, but respiratory movements due to moving diaphragm and un-comfortableness due to pressure of the transducer made the Doppler scan difficult in some buffaloes.

Similar to cows, the CEV had a wind blow like sound and the spectral display varied from a broad band with a wave like course (Fig. 6) in most of the buffaloes to a smooth broad band in a few. The CEV was scanned at a depth of 3.09±0.84 cm (2.08 to 5.45 cm) from the body surface/ transducer, and had a mean±SD diameter of 0.94±0.27 cm (0.56 to 1.68 cm) at the level of 6–7th rib. The depth of the vessel from the skin surface depends on the type and
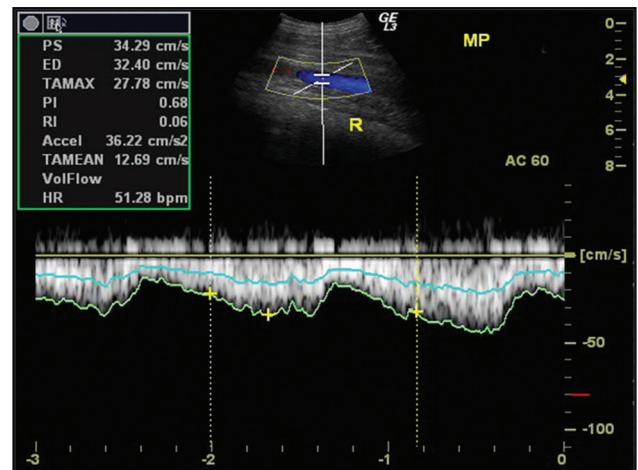

Fig. 6. Doppler scan of CEV in a healthy buffalo.

thickness of the tissue between the transducer and the vein (Braun *et al.* 2009). Since, the skin, muscle and fat thickness of a healthy buffalo is more than that of the Indian cross-bred cow; a significant increase in the depth of the CEV in buffalo was recorded compared to cow.

The body weight of buffaloes in Group 2 showed a significant positive correlation with the age (r= 0.651, P=0.002), volume flow (r=0.516, P=0.02), vessel diameter (r=0.652, P=0.002) and the depth of the vessel (r=0.509, P=0.022). The age of the buffaloes also showed significant positive correlation with the volume flow (r=0.446, P=0.049) and the depth (r=0.532, P=0.016) of the CEV. There was a significant positive correlation (r=0.797, P<0.001) between the volume flow and the vessel diameter of CEV in buffaloes. The volume flow of blood in the CEV at that point also showed significant positive correlation with the velocities; ED (r=0.448, P=0.048), TA max (r=0.505, P=0.023) and TA mean (r=0.472, P=0.035) of CEV.

Comparison of B-mode and the Doppler ultrasound findings of CEV in Groups 1 and 2: The body weight of cows in Group 1 was significantly less (P=1.1E-04) than that of buffaloes in Group 2 (Table 1). The Doppler parameters of CEV showed a significant species difference. The velocities; PS (P=3.4E-03), ED (P=1.4E-03), TA max (P=4.4E-04) and TA mean (P=2.03E-03) were significantly higher in cows compared to buffaloes. However, the PI (P=1.5E-03), RI (P=1.6E-02), vessel diameter (P=5.83E-05) and the depth of the vein (P=6.13E-04) were significantly higher in buffaloes compared to cattle. The highest percent change in the Doppler parameters of CEV in between the species was recorded in the PI followed by the RI, while the least was in the vessel diameter.

The physiology of blood flow in the CEV, as depicted by the Doppler values, suggest great differences in the two species. The cows showed significantly high blood flow velocities while the buffaloes showed higher PI, RI and vessel diameter of the CEV. The higher velocities of CEV in cows suggest a higher heart rate (Tajima and Chikamune 1989) and more forceful systole in cows when compared

to the buffaloes. This may be related to the blood pressure and the behavior/sensitivity difference of the species. The weight was significantly positively correlated to the vessel diameter in buffalo and since, the weight of the Indian buffalo is significantly more than the cross-bred Indian cattle, it might be the reason for a significant higher diameter of the CEV in buffaloes compared to cows. The larger vessel diameter also led to the increase in the volume flow of the blood in the CEV, though not significant.

Clinical and B-mode ultrasound findings in Group 3: Fifteen cows included in Group 3 had a mean±SD weight of 375.33±59.02 kg (range 300–500 kg) and were aged 4.5±1.83 years (range 2.5–10 years). No significant difference in the body weight and the age was recorded between Group 1 and 3. Partial feed intake, rumination and defecation was recorded in all the cows. One animal had the history of bloat after mild feed intake. Presence of foreign body alone was recorded in 66.67% (10) of the cattle, while, rest (5) had associated peritonitis. An increase in peritoneal fluid along with fibrin on B-mode ultrasound or adhered rumen to the peritoneum during rumenotomy was considered to be foreign body induced peritonitis (TRP). Mild clear anechoic fluid column of 2–3 cm around reticulum was taken as normal inflammatory reaction and

Table 1. Doppler values (mean±SD) for cranial epigastric vein in non-gravid clinically healthy cows (Group 1) and buffaloes (Group 2)

Variable	Group 1 Mean±SD (range)	Group 2 Mean±SD (range)	% change (Group 1 from 2)
Body weight (kg)	397.35±51.16 (325.00–500.00)	496.05±85.62** (370.00–685.00)	24.84**
Age (years)	5.30±1.86 (2.00–10.00)	6.73±2.96 (3.50–15.00)	26.98
Peak systole velocity (PS) (cm/s)	68.49±29.96 (37.84–131.52)	45.00±12.66** (26.67–76.80)	–34.29**
End diastole velocity (ED) (cm/s)	45.74±21.39 (23.59–101.82)	27.12±9.28** (9.89–46.17)	–40.71**
TA max (cm/s)	50.94±21.50 (29.53–99.07)	29.02±12.50** (5.26–63.22)	–43.03**
Pulsatility index (PI)	0.60±0.20 (0.28–0.98)	2.02±1.66** (0.42–6.04)	238.33**
Resistive index (RI)	0.33±0.11 (0.15–0.54)	0.5±0.27* (0.17–1.08)	51.51*
TA mean (cm/s)	24.81±12.82 (12.31–55.78)	13.93±6.30** (2.08–32.56)	–43.85**
Volume flow (ml/min)	483.70±412.88 (126.40–1609.60)	629.61±464.31 (106.75–1779.00)	–34.58
Vessel diameter (cm)	0.61±0.15 (0.41–1.05)	0.94±0.27** (0.56–1.68)	30.17**
Depth of the vessel from skin/transducer (cm)	2.29±0.38 (1.66–2.94)	3.09±0.84** (2.08–5.45)	54.09**

*Significant difference at $P<0.05$. ** Significant difference at $P<0.01$.

such cattle were not considered to be suffering from TRP. The extent of peritoneal fluid ranged from the peri-reticular region to left lower flank. Incomplete reticular motility was present in all the cows of Group 3.

Doppler ultrasound findings of the CEV in Group 3 in comparison to Group 1: The body weight in Group 3, had a significant ($P<0.05$) positive correlation with the PS, TA max and TA mean of the CEV, which was not present in Group 1 (Table 2). Rest of the correlations were similar to that in Group 1, except that the PI and RI were not significantly correlated to the PS and vessel diameter and the age was not significantly correlated to any of the recorded parameters.

A significant decrease in blood flow velocities PS ($P=4.5E-03$), ED ($P=3.5E-04$), TA max ($p=9.9E-04$) and TA mean ($p=6.8E-03$) was recorded in Group 3 compared to that in Group 1. The percent decrease in the velocities was higher in cows having TRP than those having traumatic reticulitis (TR) alone. A significant ($P=0.001$) reduction of 74.54% in the blood flow volume per minute was recorded in cows suffering from TRP compared to healthy. However, no significant reduction was recorded in those having TR alone. The acceleration was significantly ($P=0.016$) decreased by 45.32% in cows suffering from TR when compared to Group 1, but no significant change was found in cows suffering from TRP. There was a significant ($P=0.021$) increase in the PI (120%) in Group 3 in comparison to Group 1. However, no significant change in the PI was observed when the cows suffering from TRP and TR were compared separately to Group 1. The significant reduction ($P=0.043$) in the depth of the vein was recorded in cows of Group 3 suffering from TR alone, while this was not observed in TRP cases when compared to Group 1. The highest percent change in the Doppler values of CEV was recorded in the PI of Group 3 and the least in PS when compared to normal healthy cows.

The reduction in the volume flow/min in cows suffering from TRP compared to healthy may be due to the chronic condition, which in turn resulted in lower velocities of TRP suffering cattle. The findings suggest that presence of potential foreign body along with peritonitis is an advanced condition or a squeal (Abdelaal *et al.* 2009, Kumar *et al.* 2012) and were seen to have been altering the blood flow parameters of CEV at a larger scale compared to TR alone. The presence of peritonitis along with potential foreign body seem to be a chronic condition causing a greater and significant reduction of volume flow in the CEV compared to healthy and cattle suffering from TR alone. A greater regurgitation occurred in the blood flow of CEV in cattle having potential foreign body, which led to a significant increase in the PI, which could suggest pressure on the vessel.

Doppler ultrasound findings of the CEV in Group 5 in comparison to Group 1: There was a significant alteration in the correlations recorded in the CEV of Group 5 compared to Group 1 and 3 (Table 2). The body weight and the age had a significant negative correlation with the ED, TA max and the TA mean and the transducer distance from

Table 2. Doppler values (mean±SD) for right cranial epigastric vein (CEV) in non-gravid clinically healthy (Group 1) cows, cows suffering from TR/TRP (Group 3) and RDH (Group 5)

Variable	Group 1 Mean±SD (range)	Group 3 Mean±SD (range)	Group 5 Mean±SD (range)	% change (Group 3 from 1)	% change (Group 5 from 1)
Body weight (kg)	397.35±51.16 (325.00–500.00)	375.33±59.02 (300.00–500.00)	384.40±105.19 (200.00–450.00)	–5.54	–3.26
Age (years)	5.30±1.86 (2.00–10.00)	4.50±1.83 (2.50–10.00)	4.50±1.12 (3.00–6.00)	–15.09	–15.09
Peak systole velocity (PS) (cm/s)	68.49±29.96 (37.84–131.52)	44.59±14.64[**] (25.16–71.10)	28.86±5.25[**] (20.89–35.37)	–34.90[**]	–57.86[**]
End Diastole velocity (ED) (cm/s)	45.74±21.39 (23.59–101.82)	24.32±7.52[**] (16.05–39.33)	21.16±6.03[**] (14.08–30.47)	–46.83[**]	–53.74[**]
TA max (cm/s)	50.94±21.50 (29.53–99.07)	30.12±11.54[**] (16.59–54.57)	23.06±6.43[**] (16.92–32.78)	–40.87[**]	–54.73[**]
Pulsatility index (PI)	0.60±0.20 (0.28–0.98)	1.32±1.08[*] (0.21–3.45)	0.93±1.05 (0.20–2.73)	120.00[*]	55.00
Resistive index (RI)	0.33±0.11 (0.15–0.54)	0.44±0.23 (0.13–0.97)	0.26±0.16 (0.13–0.53)	33.33	–21.21
Acceleration (cm/s²)	171.29±123.63 (54.49–529.42)	103.53±45.80[*] (47.53–185.39)	58.71±6.76[**] (49.32–66.40)	–39.56[*]	–65.73[**]
TA mean (cm/s)	24.81±12.82 (12.31–55.78)	14.72±7.35[**] (6.70–34.71)	11.43±3.16[**] (8.34–15.38)	–40.67[**]	–53.93[**]
Volume flow (ml/min)	483.70±412.88 (126.40 –1609.60)	310.22±235.56 (88.13–758.57)	188.19±114.05[*] (49.34–334.29)	–35.87	27.89[*]
Vessel diameter (cm)	0.61±0.15 (0.41–1.05)	0.69±0.21 (0.45–1.20)	0.55±0.13 (0.35–0.69)	13.11	–61.09
Distance of the vessel from the transducer (cm)	2.29±0.38 (1.66–2.94)	2.09±0.30 (1.69–2.63)	2.12±0.96 (1.35–3.75)	–8.73	–9.84

*Significant difference at $P<0.05$. **Significant difference at $P<0.01$.

the vessel in Group 5, which was otherwise not negative in the other two groups. The PS was not significantly correlated to any of the velocities. The ED was also not significantly correlated to TA mean as recorded in Group 1. The PI and RI had a significant positive correlation with each other and the volume flow had with the TA max, TA mean and the vessel diameter. No other significant correlation between the Doppler values was recorded in Group 5 cows.

Similar to Group 3, all the velocities; PS (P=1.23E-05), ED (P=1.83E-04), TA max (P=5.74E-05), TA mean (P=3.57E-04) and the acceleration (P=6.6E-04) were significantly reduced in Group 5 compared to Group 1, and the per cent reduction was higher than Group 3 (Table 2). In contrast to Group 3, the volume flow of CEV in Group 5 cows was also significantly (P=0.0102) reduced but the PI was not significantly altered. The highest per cent change was recorded in the TA mean and the least in the volume flow per minute of the CEV in Group 5 in comparison to Group 1.

Clinical and B-Mode ultrasound findings in Group 4: Twenty buffaloes included in Group 4 had a mean±SD weight of 473.00±97.82 kg (range 280–600 kg) and were aged 6.74±2.33 years (range 4–12 years). Partial feed intake, rumination and defecation was recorded in all the buffaloes. No increase in peritoneal fluid with fibrin or echogenic contents was recorded in buffaloes of Group 4. Mild clear anechoic fluid of 2–3 cm column only around reticulum was taken as normal inflammatory reaction.

Correlations within the Doppler variables of CEV in Group 4: The correlations of body weight and age altered from normal. In contrast to normal, the body weight was only significantly positively correlated to the depth of the vein and the age to the vessel diameter. The correlations between the velocities and between the PI and RI remain the same as in normal, except, the negative correlation of PI and RI with the TA mean and TA max was not significant in Group 4. In group 4, the volume flow had significant positive correlation with the TA mean and the diameter of CEV only.

Differences between the Doppler variables of CEV in Group 2 and Group 4: The PS of CEV was recorded to be mildly but significantly (P=0.034) increased by 4.65% in the buffaloes of Group 4 when compared to Group 2. No other significant difference was observed.

Clinical and B-mode ultrasound findings in Group 6: Fifteen buffaloes included in Group 6, had a mean±SD weight of 398.33±64.36 kg (range 250–480 kg) and were aged 6.4±1.5 years (range 3.5–9 years). The body weight was significantly lower by 19.7% than that of the buffaloes in Group 2 (P=0.00051) and by 15.79% from Group 4 (P=0.01). Partial feed intake, rumination and hard to loose, black colored feces were recorded in all the buffaloes. The buffaloes had the history of illness since 1–4 months. No increase in peritoneal fluid was recorded in buffaloes of Group 6. The hernial rings in all the buffaloes included in

Table 3. Doppler values (mean±SD) of CEV in non-gravid healthy buffaloes (Group 2), buffaloes suffering from TR/TRP (Group 4) and RDH (Group 6)

Variable	Group 2 Mean±SD (range)	Group 4 Mean±SD (range)	Group 6 Mean±SD (range)
Body weight (kg)	496.05±85.62 (370.00–685.00)	473.00±97.82 (280.00–600.00)	398.33±64.36 [**] (250.00–480.00)
Age (years)	6.73±2.96 (3.50–15.00)	6.74±2.33 (4.00–12.00)	6.40±1.50 (3.50–9.00)
Peak systole velocity (PS) (cm/s)	45.00±12.66 (26.67–76.80)	59.85±27.00 [*] (19.53–131.11)	41.41±12.43 (28.01–71.56)
End diastole velocity (ED) (cm/s)	27.12±9.28 (9.89–46.17)	31.70±14.45 (10.46–61.41)	25.52±12.55 (12.03–61.18)
TA max (cm/s)	29.02±12.50 (5.26–63.22)	36.55±20.46 (4.00–87.40)	27.62±12.69 (16.50–66.00)
Pulsatility index (PI)	2.02±1.66 (0.42–6.04)	1.92±1.14 (0.56–4.02)	2.10±1.54 (0.21–6.15)
Resistive index (RI)	0.50±0.27 (0.17–1.08)	0.61±0.36 (0.09–1.42)	0.44±0.22 (0.15–0.91)
Acceleration (cm/s²)	77.26±32.89 (31.97–149.84)	125.15±109.03 (26.81–530.18)	83.66±37.74 (32.56–167.12)
TA mean (cm/s)	13.93±6.30 (2.08–32.56)	16.60±9.94 (1.72–39.85)	13.29±6.17 (7.06–31.19)
Volume flow (ml/min)	629.61±464.31 (106.75–1779.00)	638.10±541.50 (73.37–1787.30)	416.92±276.45 (87.13–1176.00)
Vessel diameter (cm)	0.94±0.27 (0.56–1.68)	0.84±0.34 (0.41–1.74)	0.80±0.24 (0.53–1.32)
Distance of the vessel from the transducer (cm)	3.09±0.84 (2.08–5.45)	2.83±0.88 (1.08–4.44)	2.64±0.89 (1.45–4.40)

*Significant difference at P<0.05. **Significant difference at P<0.01.

the study were on the right side of the medial plane. Presence of penetrating potential foreign body/bodies in the herniated reticular sac was recorded in 33.33% (n=5/15) buffaloes, while presence of potential foreign body/bodies in the abdominal reticulum was recorded in 13.33% (n=2) of the buffaloes. The two buffaloes had potential foreign body in both the abdominal and herniated reticulum. Rest of the buffaloes had no foreign body on radiograph.

Correlations within the Doppler variables of CEV in Group 6: The correlations were found altered from the Group 2, except for the velocities. Similar to Group 4, the body weight was significantly positively correlated to the depth of the vein only. The age was not correlated to any of the parameter. The significant correlations of the PI with other parameters were not significant. In contrast to Group 2 and 4, the negative correlation of the acceleration with the volume flow and vessel diameter was significant in Group 6.

The depth of the vein was significantly positively correlated to the vessel diameter and the volume flow only.

The body weight of buffaloes suffering from RDH was more reduced compared to those suffering from TRP. However, Doppler values of CEV are not significantly influenced by the reticular conditions TR and RDH in buffaloes. Only the PS of CEV was recorded to be mildly higher in buffaloes suffering from traumatic reticulitis. Compared to cows, a significant species difference was noticed. The cow CEV was seen to be greatly influenced in the reticular conditions; TR and RDH, especially for the velocities, PI and volume flow.

Differences between the Doppler variables of CEV in Group 2 and Group 6: No significant difference in the Doppler values was recorded in Group 2 and Group 6.

Differences between the Doppler variables of CEV in Group 4 and Group 6: The PS of CEV was recorded to be significantly (P=0.01) increased by 30.81% in the buffaloes of Group 4 when compared to Group 6.

The database generated for non-gravid crossbred Indian cows and buffaloes can be used as a reference range for further studies. There are significant differences in the B-mode and the Doppler blood flow values of the cranial epigastric vein in cows and buffaloes. These might help in understanding species difference in the circulatory physiology and the anatomy of the two species and relating them to the reticular disorders.

In disease conditions like TRP and RDH, the blood Doppler physiology of CEV is more significantly affected in cows compared to that in buffaloes.

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