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RESEARCH ARTICLE

Computed Tomography in Polytraumatized Patients: A Retrospective Study of 63 Cases (2014-2017)

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ABSTRACT

This study aimed to identify the regions and lesions most frequently reported in polytraumatized dogs and cats undergoing computed tomography. Research was carried out in the database of three Veterinary Referral Centers, to identify traumatized dogs and cats undergoing computed tomography from 2014 to 2017. Following were collected for each patient: gender, weight, type of study carried out and injuries reported. Lesions were classified according to the region involved: head, spine, chest, abdomen, pelvis, and appendicular skeleton. Thirty-seven studies involving cats and 26 involving dogs were included. Cats mainly presented lesions that involved both the skull and the chest simultaneously. Dogs presented lesions that affected the chest, abdomen and vertebral column simultaneously. In cats, the skull was more affected than in dogs (P<0.001). Of the cranial bone structures, more lesions were reported of the mandible and maxilla in cats (43%), and dogs were more affected by thoracic trauma (P<0.0011), by lesions of the vertebral column (P<0.008) and abdominal trauma (P<0.012). The thoracic findings included pulmonary contusions (dogs 54%, cats 24%) and pneumothorax (dogs 38%, cats 11%). Computed tomography in polytraumatized dogs and cats allowed a proper evaluation of the lesions and reduced the time between diagnosis and treatment.

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INTRODUCTION

Polytrauma is a severe injury involving two or more areas of the body (Kroupa, 1990). In small animal practice, most common polytrauma are road traumatic accidents (RTA), high-rise syndrome and bite wounds (Crowe, 2006; Dozeman *et al.*, 2020). Thoracic trauma is the prevalent injury in dogs and cats with evidence of pneumothorax and lung contusion while hemoperitoneum is reported as the most common abdominal injury (Dozeman *et al.*, 2020). The clinical complexity and diagnosis of a polytrauma are therefore determined by the presence of injuries in more than one region; one study has reported that approximately 50% of dogs with thoracic lesions also presented skeletal fractures while other associated injuries affected the nervous system and abdomen (Kolata and Johnston, 1975).

Consequently, the use of only a single first-level diagnostic method is not sufficient for diagnosing trauma in all regions (Oliveira *et al.,* 2011; Fields *et al.*, 2012; Shanaman *et al.,* 2013). In human medicine, in the case of major trauma, the diagnostic protocol involving radiography of the chest, the cervical spine and the pelvis, and thoracic and abdominal echography is followed by total body computed tomography (CT) only in case of positivity to one of the previous exams (Scaglione, 2012).

According to the new Advanced Trauma Life Support (ATLS) guidelines, multi-slice CT represents the gold standard since it provides a fast and complete overview of the injuries; it enables the identification of effusions and lacerations of organs, and the use of a contrast medium allows the identification of active hemorrhage leading to immediate therapeutic intervention (Scaglione, 2012).

The main limitation of the application of this method in veterinary medicine is represented by anesthesia which requires a stable patient. The introduction of new devices, such as transparent boxes in plexiglass, and the use of sedation should be sufficient to carry out CT rapidly, obtaining a diagnostic scan with minimal moving artifacts (Oliveira *et al.*, 2011).

This study aimed to describe the major CT findings that occurred in polytraumatized dogs and cats, the frequency of distribution of the lesions associated with the main body's regions involved, and the differences arising between these species.

MATERIALS AND METHODS

This study conducted at Veterinary Hospital "Portoni Rossi" in Bologna, at Veterinary Hospital "Mario Modenato" of Pisa University, and Veterinary Clinic "Pet Care" in Bologna from 2014 to 2017. Medical records of traumatized dogs and cats that underwent CT were retrospectively evaluated. The study protocol was in accordance with institutional guidelines for research on animals; the owners of dogs in our study were fully informed of the procedures and written informed consent was obtained.

Each patient received methadone (0,1- 0,2 mg/kg IV) followed by propofol (2-4 mg/Kg IV) and then intubated with a cuffed endotracheal tube. Anesthesia maintenance was achieved with a mixture of sevoflurane and oxygen.

General anesthesia was performed in all patients, except for a cat that was studied under sedation with methadone (0,1 mg/kg IV) and dexmedetomidine (1 mcg/kg/h CRI).

The CT studies were carried out using 16 slices (Toshiba Aquilion 16 in Bologna, GE BrightSpeed in Bologna), and 2 slices (GE high Speed in Pisa) machines. For each patient, the following data were collected: gender, weight, region surveyed, use of contrast medium, decubitus. The patients have been studied in sternal recumbency unless a spinal fracture/luxation was suspected. In those cases, the studies were taken in lateral recumbency, minimizing the movement of the vertebrae due to positioning. The slice thickness was 1.2 mm for the multislice units (Bologna), and 1.2 to 2.5 mm for the dual slice unit (Pisa). The contrast agent, ioversol at a dose of 600 mg/kg Iodine and a volume of 2 ml/kg (Optiray 300, Milan, Italy) was administered via power injector at a speed rate of 2 ml/sec.

The traumatized patients were first subjected to radiographic and ultrasound studies and CT studies were subsequently performed to identify previously undetected lesions.

The considered computed tomography studies can be divided as follows: 41 total body studies, 20 studies targeting the skull, 1 examination of the pelvis and the spine, and 1 study of the thorax and abdomen only (Table 1).

The injuries were organized according to a reference scheme which included the skull, chest and abdomen, and the axial and appendicular skeleton.

The results were first illustrated for each group according to the species they belonged to. The probability of injury to the different regions (skull, thorax, abdomen, vertebral column, pelvis) was then compared in the two groups, dogs and cats, as was the percentage of specific alterations to the regions of prevalent interest (skull and thorax).

Statistical analysis: The analyses were carried out using the statistical software Graph Pad Prism 7. For each group (cats/dogs), the percentages relating to injuries in the skull, chest, abdomen, skeleton, and hip bones were obtained. The comparison of data between the two groups was performed using the exact Fisher test for proportions. The odds ratio was applied to describe the ratio in terms of the probability that an event occurred in one group (cats) with respect to the probability that it occurred in the other group (dogs). Values of $P<0.05$ were considered significant.

RESULTS

The study included 37 cats and 26 dogs for a total of 63 CT studies. There were 13 male cats (11 castrated and 2 entire), and 24 female cats (14 sterilized and 10 entire). There were 14 female dogs (one sterilized and 13 entire) and 12 male dogs (one castrated and 11 entire). The average weight of the cats was homogeneous with a value of 4.26 kg (2 Kg to 5.2 Kg) and there was a wide range, from 3 to 31 kg, with an average weight of 13.8 kg within the dogs.

22 dogs were referred for a Road traffic accident (RTA) and 4 dogs were presented for blunt trauma. 21 cats were referred for an RTA and 16 for high-rise syndrome (HRS).

Results: cats (group A): The studies included can be classified as follows: 16/37 (43%) total body CTs with iodinated contrast agent administration, 3/37 (8%) plain total body studies; 17/37 (44%) targeting only the skull (14 pre/post-contrast and 3 plain) while 1/37 (4%) involved only the pelvis and vertebral column.

Injuries to the skull were reported in 29/37 patients (78%). Chest lesions were reported in 13/37 of the cats 35% while vertebral and abdominal lesions were present in 5/37 of cases (13%). The pelvis showed lesions in 3/37 cases (8%). Considering the skull in particular 16/37 cases (44%) reported fractures in the mandible as well as in the maxilla. Their simultaneous involvement was reported in 10/37 cases (27%). The nasal plane was subjected to lesions in 12/37 subjects (32%), the zygomatic bone in 9/37 (24%), the orbit in 5/37 (13%), the frontal bone in 4/37 (11%), the temporal bone in 3/37 (8%), and sphenoid bone in 1/37 (4%) (Fig. 1).

Thoracic trauma caused pulmonary contusions in 9/37 cases (21%). Pneumothorax was found in 4/37 of the traumatized cats (11%), rib fractures in 3/37 (8%), and pleural effusion was found in 2/37 (6%). Hernias of the small bowel through the abdominal wall were found in 2/37 (6%) of cats as well as bladder rupture 2/37 (6%). Only one cat reported 1/37 (3%) retroperitoneal effusion.

Considering the different regions together, it was evident that simultaneous skull and thorax lesions occurred in 7/37 cases (20%); damage to the skull, thorax and vertebral column in 2/37 cases (6%). The skull, together with the vertebral column showed lesions in 1/37 (3%), 1/37 (3%) had chest-vertebral column injury and 1/37 (3%) had abdominal-pelvis involvement. The thorax, abdomen, and vertebral column were all involved in a single case as was the chest-abdomen-pelvis. In the CT images, regarding the appendicular skeleton, there was 1/37 (4%) fracture of the radius and ulna and 1/37 (4%) of the metacarpals.

Table 1: Target and total numbers of CT studies performed

CT Target	Numbers of CT studies
Total body	41/65
Skull	20/65
Pelvis and spine	1/65
Thorax and abdomen	1/65

Table 2: CT findings associated with the main region involved in cats

Group A: cats (37)		
Region	Findings	N.
Skull	- mandibular fracture	16
	- maxillar fracture	16
	- nasal bone fracture	12
	- zygomatic bone fracture	9
	- sphenoid bone fracture	9
	- frontal bone fracture	4
	- orbital bone fracture	5
	- temporal bone fracture	3
Chest	- pneumothorax	4
	- lung contusion	9
	- rib fractures	3
	- pleural effusion	2
Abdomen	- bladder rupture	2
	- abdominal hernia	2
	- retroperitoneal effusion	1
Pelvis	- Sacro-iliac luxation	2
	- Ileal fracture	2
Appendicular skeleton	- monolateral radial fractures	1
	- metacarpal bones fractures	1
Vertebral	- T11 fracture	1
Column	- T13 fracture	1

Table 3: CT findings associated with the main region involved in dogs

Group B: dogs (26)		
Region	Findings	N.
Skull	- mandibular fracture	2
	- maxillar fracture	3
	- nasal bone fracture	4
	- sphenoid bone fracture	3
	- frontal bone fracture	4
	- temporal bone fracture	1
	- parietal bone fracture	1
Chest	- pneumothorax	10
	- lung contusion	14
	- rib fractures	5
	- pleural effusion	5
Abdomen	- bladder/urethra damage	2
	- diaphragmatic hernia	1
	- abdominal hernia	1
	- splenic/hepatic damage	2
	- abdominal effusion	1
	- retroperitoneal effusion	1
Pelvis	- pelvic fracture	7
	- pubic fracture	4
	- ileal fracture	4
	- sacral fracture	5
	- ischial fracture	3
Appendicular skeleton	- humeral fracture	1
	- scapular fracture	1
Vertebral column (VC)	- C4-C5 luxation	1
	- T11-T12 luxation	3
	- T12-T13 luxation	1
	- L3 fracture	1
	- L4 fracture	1
	- L7-S1 luxation	3

Table 4: Statistical comparison of the percentage of regions involved between the two groups (A, B)

Regions	% cats	% dogs	P value	ORs
Head	78	31	0.001	6.34
Thorax	35	69	0.001	0.17
Abdomen	13	42	0.02	0.21
Pelvis	8	27	0.07	n/a
Vertebral column	13	46	0.008	0.18

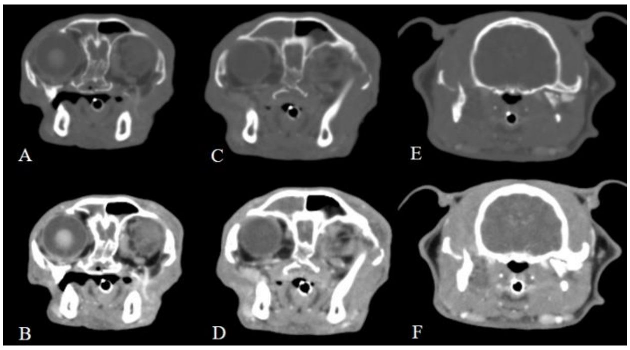

Fig. 1: A-F. Five-year-old neutered female Dsh cat Bone (A, C, E) and soft tissue windows after contrast administration (B, D, F). Multiple skull fractures are visible. The CT study gives important information especially for the comminuted fracture of the sphenoid bone, the lamina interna of the right frontal bone, and the left mandibular condyle. Thick fluid attenuation material and a fluid level are present respectively in the right and left frontal sinuses as well as in the caudal nasal cavity and nasopharynx, consistent with haemorrhage.

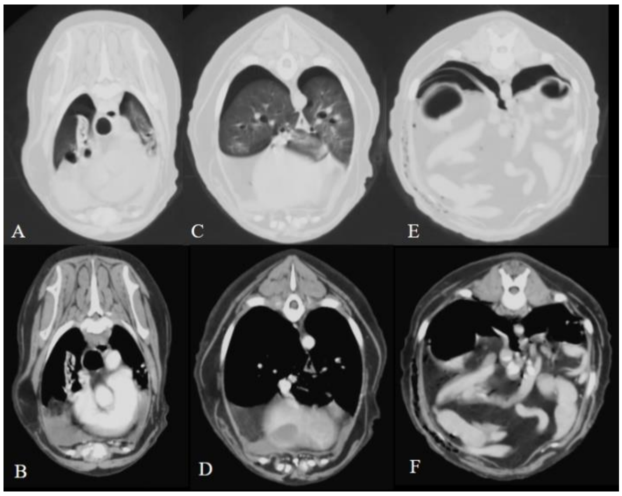

Fig. 2 A-F: Eight-year-old neutered female mixed breed dog. Lung (A, C, E) and soft tissue windows after contrast administration (B, D, F). Bilateral pneumothorax and pleural fluid are visible, as well as fat between the collapsed lung and fluid on the right side (A-D). In the abdominal wall and cavity gas bubbles are visible. The final diagnosis was bilateral pneumothorax and pleural effusion, diaphragmatic rupture with abdominal fat herniated within the thorax.

Results: dogs (group B): The studies included can be classified as follows: 22/26 (85%) total body CTs before and after the administration of an iodinated contrast agent, 3/26 (12%) CTs of the skull (2 direct with contrast agent administration and 1 plain study) and 1/26 (4%) of the chest and abdomen (pre and post-contrast medium). All the examinations were carried out under general anesthesia except for one in which sedation alone was sufficient. The skull showed lesions 8/26 (30%) of (), the thorax in 18/26 (69%), the abdomen in 11/26 (42%) and the vertebral column in 12/26of cases (46%), while the pelvis was affected in 7/26 of cases (27%). Regarding the skull: 5/26 (19%) of the lesions were at the level of the nasal bone; the frontal bone and the temporal bone were affected in 4/26 (15%) of cases. The sphenoid and maxilla presented fractures in 3/26 (11%) of cases. The mandible was involved in 2/26 (7%) of cases. Only 1/26 (4%) dog presented lesions on the parietal and frontal bone. Thoracic trauma caused pulmonary contusions in 53% of cases (14/26). Pneumothorax was found in 10/26 (38%) of the

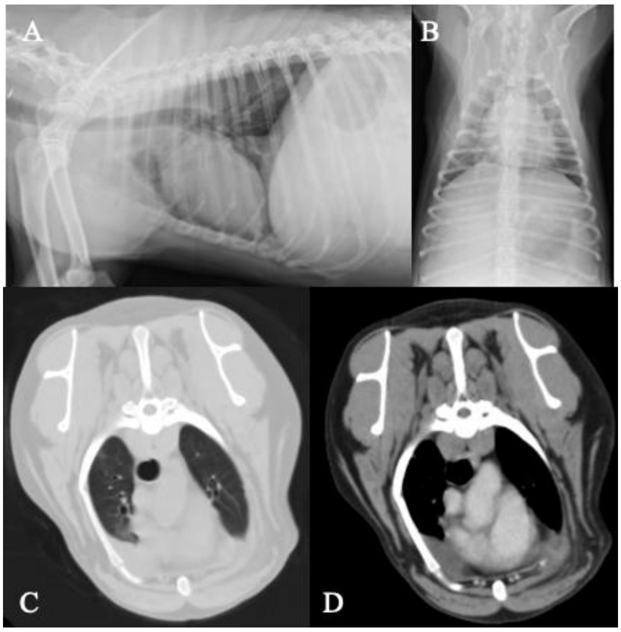

Fig. 3 A-D: 12-year-old entire male Border Collie. Right lateral and DV view of the thorax show a fracture of the 5th right rib (A-B). The CT study shows the rib fracture and mild plerual fluid on the right emithorax (C-D), non-visible in the radiographic study.

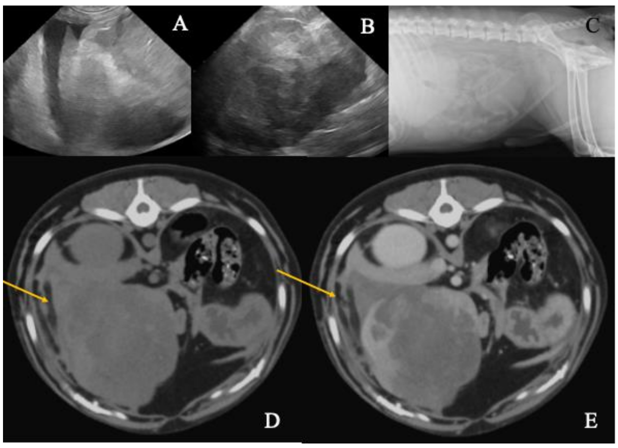

Fig 4 A-E: 12-year-old entire male Border Collie. Lateral projection of the abdomen (A) shows a loss of abdominal detail in the middle abdomen, with enlarged liver. In the US study (B-C) a mild amount of free abdominal fluid and heterogeneous area adjacent to the right lobe of the liver are visibile. Plain (D) and post contrast (E) CT, clearly show a large mass lesion of the right middle lobe of the liver, consisting with hematoma, and free abdominal fluid. Interestingly there is an unenhanced clot sign (arrows), hyperdense to the fluid, suggesting the area of the liver rupture. The lesion was surgically confirmed.

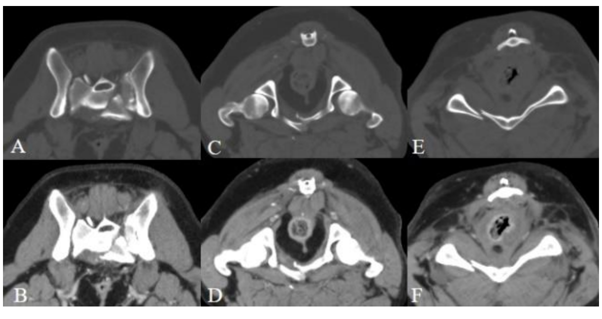

Fig. 5 A-F: Five-year-old male mixed breed dog. Bone (A, C, E) and soft tissue windows after contrast administration (B, D, F). Comminuted and displaced fracture of the body of the sacrum, and displaced fracture of the os pubis and right ischium are present. The dog was in sternal position because of concurrent thoracic lesions.

Table 5: Comparison of the number of single regions involved in polytraumatized cats and dogs (A, B)

Single region involved in cats		Single region involved in dogs	
Skull	29/37	Thorax	18/26
Thorax	13/37	Pelvis	12/26
Abdomen	5/37	Abdomen	11/26
Pelvis	4/37	Skull	8/26
Vertebral column	2/37	Scapula	7/26
Radius	1/37	Homerus	1/26
Metacarpal bone	1/37	Vertebral column	1/26

Table 6: Comparison of the number of simultaneous regions involved in polytraumatized cats and dogs (A, B)

Simultaneous regions involved in cats		Simultaneous regions involved in dogs	
Skull/thorax	7/37	Skull/thorax	3/26
Skull/Thorax/VC	2/37	Skull/VC	10/26
Skull/vertebral column	1/37	thorax/abdomen/VC	8/26
Thorax/Vc	1/37		
Abdomen/pelvis	1/37		

traumatized dogs, while rib fractures and pleural effusion were observed in 5/26 (19%). Abdominal effusion was observed in 3/26 (11%) of cases as was splenic trauma while hepatic, bladder, and urethral damage in 2/26 (7%). Hepatic trauma was always associated with abdominal effusion. Retroperitoneal effusion was reported in one dog 1/26 (4%) as well as small bowel herniation, and diaphragmatic rupture (Fig. 2).

The vertebral lesions were found more frequently at the lumbar level in 5/26 cases (19%) (L7-S1: 3; L4: 1; L3: 1). The thoracic vertebrae were involved in 4/26 cases (15%) (T11-12: 3, T12-13: 1) while the cervical region (C4-C5) was involved in only 1 patient 1/26 (4%). The fractures of the pelvis were found mainly in the sacrum in 5/26 (19%) cases, at the level of the ileum and pubis in 4/26 (15%) cases while the ischium had lesions in 3/26 (11%) cases (Fig. 3). The regions involved simultaneously were numerous because all dogs were polytraumatized. The skull and thorax were involved in 3/26 (11%) cases, the skull together with the vertebral column in 10/26 (38%), and 8/26 (31%) had lesions in the thorax, abdomen and vertebral column. Regarding the front limbs, 1/26 (4%) fractures of the scapula (1/26) and the 1/26 (4%) humeral fracture were found in dogs.

Comparison between groups A, B: Head injury was the most represented lesion in cats (78%) compared to dogs (31%) ($P<0.001$, OR = 6.34). In particular the mandibular and maxillar fractures were both observed in 43% of cats while in dogs the mandibular and maxillar fractures were 7% (P = 0,002 OR = 9,14) and 11% (P = 0,006 OR = 6,1) respectively. Thoracic trauma was 35% in cats 69% in dogs, ($P<0.001$, OR = 0,17) Pulmonary contusions 24% in cats and 54% in dogs (P = 0.03, OR = 0,27); pneumothorax was 11% in cats and 38% in dogs (P = 0.014; OR = 0,19). Vertebral column was 13% in cats and 46% of dogs. ($P<0.008$, OR = 0,18). Abdominal injury was 13% in cats and 42% in dogs ($P<0.02$, OR = 0,21). Pelvis involvement was observed in 8% of cats and 27% of dogs ($P<0.05$). In the polytraumatized cats, head and thorax were the parts most involved, while in polytraumatized dogs the thorax, abdomen, and column were simultaneously involved.

DISCUSSION

The cases in this study were considered to have been victims of a major trauma, which resulted in single or multiple injuries, potentially endangering the patient's life. In all of these cases, CT was included as a diagnostic examination to provide complementary images after the use of radiography and ultrasonography which proved to be insufficient. Indeed, in cases of suspected fractures of the skull or vertebral column, radiographs were often of limited value, while CT showed clearly the localization and number of lesions. Also, dogs weighing more than 25 kilos, the ultrasonographic assessment may be unable to detect clinically relevant lesions (Fields *et al*., 2012). For this reason, not all the studies carried out were total body tests; some had specific targets, such as the skull and pelvis. In human medicine Whole-Body Computed Tomography (WBCT) is now a key step in the initial assessment of polytrauma patients in major trauma centres ((Harvery and West, 2013; Adiotomre *et al*., 2014; Shannon *et al*., 2015), reducing mortality in polytrauma victims when compared to selective CT (Huber-Wagner *et al*., 2009; Kimura and Tanaka, 2013).

Computed tomography studies were carried out in sternal recumbency for almost all of the animals and although the positioning in some examinations was not perfectly symmetrical, it was accepted to reduce patient stress. In cases of suspected vertebral fracture, studies were taken in lateral recumbency, thus minimizing the movement of the vertebrae due to positioning.

As reported by Lopes *et al*. (2005), between the cranial bone structures in cats, mandibular fractures constituted from 11.3 to 23.1% of all fractures while, in dogs, they ranged from 1.5 to 6% (Leidner *et al.*, 1998, Lopes *et al.*, 2005). The mandible and maxilla had lesions in fewer than 1% of cases (Egger,1993; Umphet and Johnson, 1998; Lopes *et al*., 2005; Bar-Am *et al*., 2008). Also, in the CT studies of children following a motor vehicle collision, mandibular fractures were observed in 43.1% of cases; in our study, 43% of cats presented mandibular fractures (62% after RTA, 38% after HRS) while dogs reported this lesion only in 7% of cases after RTA (Wong *et al.*, 2016).

In dogs, as reported by Simpson *et al.* (2009) and Kirberger *et al*. (2017), pulmonary haemorrhage affected 58% of patients, pneumothorax 47%, rib fractures 14% and pleural effusion (haemothorax) 18% (Simpson *et al.*, 2009; Kirberger *et al.*, 2017).

In our study, it can be observed that the most common thoracic lesions in dogs and cats are pulmonary contusion present in 53% of dogs and 21% of cats respectively (Fig. 3).

The data reported by our study regarding the frequency of pneumothorax and rib fractures agree with the data reported in the literature (Simpson *et al.*, 2009; Kirberger *et al.*, 2017).

In human medicine literature, there are discordant values regarding the incidence of pulmonary contusions in people after trauma. Pulmonary contusions have been estimated to affect 30-70% of injured patients (Pal *et al.*,1988; Primack and Collins, 2002; Sangester *et al.*, 2007). Whilst Sampson *et al*. (2006) and Traub *et al*. (2006) stated that lung contusions comprised 40% of cases, Turkalj *et al*. (2014) reported that these lesions were found in a higher rate of 77.1% (Sampson *et al.*, 2006; Traub *et al.*, 2007; Turkaly *et al.*, 2014).

Many studies report the association of thoracic lesions with others in different parts of the body. As reported by Turkalj (2014), a chest injury was associated with injuries to other body regions in 80.3 % of patients (Turkaly *et al.*, 2014). In our study, the cats involved had simultaneous skull and thorax lesions. As reported by Shorr *et al*. (1987) and Sampson *et al*. (2006), also in human medicine thoracic injuries were most commonly associated with head injuries (Shorr *et al.*,1987; Sampson *et al.*, 2006).

The liver is the most commonly injured abdominal organ despite its well-protected position (Fig. 4) (Feliciano, 1998; She *et al.*, 2016). In Human Medicine, hepatic injuries are common in patients with chest trauma with costal cartilage fractures (13%) versus patients with chest trauma without cartilage fractures (4%) (Nummela *et al.*, 2017). In this study, only a dog with rib fractures also presented with a hepatic hematoma.

The spleen is commonly injured whilst the intestines less so (Pothmann *et al.*, 2018). In our study, splenic lesions were found in 7% of dogs. In human medicine, the incidence of splenic vascular lesions identified with CT examinations was significantly higher (59.3%) (Margari *et al.*, 2018).

With severe pelvic trauma in human beings, CT scanning has been useful in the detection of rupture of the bladder or urethra and the entrapment of intestine by fracture fragments (Catsikis *et al.*, 1989; Charnley and Dorrell, 1993; Pao *et al.*, 2000; Hsieh *et al.*, 2002). In human beings, small bowel and mesenteric traumas are relatively uncommon, occurring in approximately 3-5% of patients undergoing laparotomy for blunt abdominal trauma (Brownstein *et al.*, 2000).

Due to the box-like characteristics, fractures of the pelvis (Fig. 5) were observed at several points involving the ileum, ischium, and pubis (Stieger Vanegas *et al.*, 2015).

In the dogs, multi-planar reconstruction two-dimensional CT was used to classify pelvic fractures in view of surgery, or to verify the presence of suspected acetabular fractures in stable subjects from a haemodynamic point of view (Crawford *et al.*, 2003); on the contrary, in humans, the study of this region is fundamental since unstable pelvic fractures with interruption of the pelvic ring, in two or more points, are sometimes associated with hypovolemic shock due to severe bleeding from concomitant vascular lesions (Cerva *et al.*, 1998).

In human medicine, the finding of active bleeding, evident in CT images as an active extravasation of contrast medium in an irregular way, has been reported in 13-18% of patients with pelvic fractures (Willman *et al.*, 2002).

Vertebral lesions have been found more frequently at the lumbar level between L7-S1 and L3-L4 and at the thoracic level T11-T12 and T12-T13, the section which acts as a fulcrum between moving and rigid parts (Selcer *et al.*, 1991).

Lesions on the appendicular skeleton were poorly represented. In this study, fractures were present in 7% of cases, and fractures of the radius and ulna were observed in 2% of cases as reported by Simpson *et al*. (2009). Femoral fractures were found only in 7% of cases unlike the 16% reported in the previously mentioned report.

In the case of being struck by a vehicle, skin lesions (abrasions, subcutaneous emphysema) and muscle damages were also associated (Culp and Silverstein, 2009).

Conclusions: In veterinary medicine, the use of CT in cases of major trauma is still very limited. This type of imaging is not often present in veterinary clinics. Also, the need for anesthesia does not always allow unstable patients to be studied. However, with multidetector CT units, it is now possible to study the unstable patients under sedation, as it was done in this study for a cat. As can also be seen from this study, CT is an excellent tool for defining lesions in polytrauma, reducing the time between diagnosis and treatment. Unlike human medicine, there are no studies which correlate the time spent in the emergency room of patients undergoing CT, and their respective survival rate as compared to those who follow the classic protocol.

Authors contribution: F. Serra, GA, SC, MV designed the retrospective study. All authors were involved during the Imaging evaluation. MV revised each report. All authors critically interpreted the data and they all authorized the final version of the manuscript.

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