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Scientific Article

Intra-observer comparison between conventional and oblique radiography of the pelvis of polytraumatized cats and dogs

Comparação intra-observador entre radiografia convencional e oblíqua da pelve de gatos e cães politraumatizados

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ABSTRACT - Many bone lesions are missed by plain radiography in small animals with polytrauma in the pelvis due to the many bone overlaps.Thus, this study aimed to compare intra-observer agreement between the conventional two-projection technique (laterolateral and ventrodorsal; LL and VD) and the 45° rolling projection (right/left ventromedial oblique to dorsolateral flexed leg; OBL) in the evaluation of fractures and dislocations in polytraumatized animals. The images were evaluated intra-observer by two radiologists (control group) and compared with the evaluation of two orthopedists,residents and students. When comparing fractures between the projections, a statistical difference was observed between the three projections, LL, VD, and OBL (N=288, df= 2, wald= 24.7 p= 0.0000). The VD projection (n=188) was the most efficient, followed by the OBL (n=174) and the LL (n=105). For the evaluation of sacroiliac dislocations, it was found that the VD (n=33) and OBL (n=33) projections were equal and more sensitive than the LL (n=0) (N= 288, df=2, Wald= 1964.2, P<0.01-10). In the intra-observer comparison, it was not possible to observe a significant difference in the assessment of fractures, even though the group of radiologists observed a greater number of injuries. In general, abnormalities (fractures and dislocations) were seen with greater accuracy in the VD view (n=237), followed by the OBL (n=225) and LL (n=120) (N= 288, df=2, Wald = 40.2, P<0.01-10). The study suggests that evaluation by a radiologist should be preferred and that the OBL projection should also be included in the feline routine as it reduces bone overlap.

Keywords: Pelvic cavity. Small animals. Pubis. Orthopedics.

RESUMO - Muitas lesões ósseas não são detectadas pela radiografia simples em pequenos animais com politraumatismo na pelve devido às muitas sobreposições ósseas. Assim, este estudo teve como objetivo comparar a concordância intraobservador entre a técnica convencional de duas projeções (laterolateral e ventrodorsal; LL e VD) e a projeção rolante de 45° (oblíqua ventromedial direita/esquerda para perna flexionada dorsolateral; OBL) na avaliação de fraturas e luxações em animais politraumatizados. As imagens foram avaliadas intraobservador por dois radiologistas (grupo controle) e comparadas com a avaliação de dois ortopedistas, residentes e estudantes. Ao comparar as fraturas entre as projeções, foi observada diferença estatística entre as três projeções, LL, VD e OBL (N=288, df= 2, wald= 24,7 p= 0,0000). A projeção VD (n=188) foi a mais eficiente, seguida da OBL (n=174) e da LL (n=105). Para a avaliação das luxações sacroilíacas, verificou-se que as projeções VD (n=33) e OBL (n=33) foram iguais e mais sensíveis que a LL (n=0) (N= 288, df=2, Wald= 1964,2, P<0,01-10). Na comparação intraobservador, não foi possível observar diferença significativa na avaliação das fraturas, embora o grupo de radiologistas tenha observado maior número de lesões. Em geral, as anormalidades (fraturas e luxações) foram vistas com maior precisão na visão VD (n=237), seguida pela OBL (n=225) e LL (n=120) (N= 288, df=2, Wald = 40,2, P<0,01-10). O estudo sugere que a avaliação por um radiologista deve ser preferida e que a projeção OBL também deve ser incluída na rotina felina, pois reduz a sobreposição óssea.

Palavras-chave: Cavidade pélvica. Pequenos animais. Púbis. Ortopedia.

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INTRODUCTION

Domestic animals with access to the outdoors are often treated by veterinarians due to trauma without a detailed history, with radiography as the first modality of choice and pelvic fractures being the third most prevalent (ZULAUF et al., 2008) or representing 20–22% in other studies (BOOKBINDER; FLANDERS, 1992; LANGLEY-HOBBS et al., 2009). The importance of pelvic fractures (27%, 54 felines) is reported in another study with 215 cases of patellar fracture and dental anomaly syndrome (PADS) (RODRIGUEZ et al., 2021).

Pelvic fractures result in long-term complications, narrowing of the pelvic canal, constipation, neurological deficits, degenerative joint diseases, and joint pain (LANZ, 2002). Multiple fractures generally occur with three or more bones involved; they are rarely exposed (PIERMATTEI; FLO, 2006; CRAWFORD; MANLEY; ADAMS, 2003), and the acetabulum fracture represents up to 26%, although it may be underestimated due to the causes of overlaps in the radiographic examination (HAINE et al., 2019).

Pelvic trauma is generally diagnosed by associating clinical examination and imaging diagnosis. Due to the anatomical complexity and bone conformation

of the pelvis, computed tomography (CT) has been shown to be superior in detecting pelvic fractures (STIEGER-VANEGAS et al., 2015) as it allows a high level of detail of the bone and joint anatomy. However, the radiographic technique is still the method of first choice (VETTORATO; MARCELINO; SILVA, 2017).

For a better visualization of the pelvis through radiographic projections, it is necessary to perform different positions (FROES et al., 2009). Nevertheless, in the routine of small animals, only lateral (LL) and ventrodorsal (VD) projections are used. Therefore, the possible addition of oblique projections (OBL) is recommended to reduce overlaps (CRAWFORD; MANLEY; ADAMS, 2003; HARASEN, 2007; HENRY, 2013). According to Reis et al. (2014), oblique positioning allows exposure of the hemipelvic bones, thus obtaining a better definition of the acetabulum, fracture lines, and positioning of the fragments.

Stieger-Vanegas et al. (2015) studied eleven dogs, demonstrating the superiority of CT compared to the VD, right/left LL, and the right and left ventral-45°medial to dorsolateral oblique frog leg ("rollover 45-degree view") view and observed that OBL projections allowed better visualization of the fractured fragments. Thus, this study aimed to perform an intra-observer comparison of radiographic techniques for the pelvis: the conventional technique (laterolateral [LL] and ventrodorsal [VD]) and the oblique rollover 45-degree view technique (right and left ventral-45° medial to dorsolateral oblique frog-leg view) in the evaluation of fractures (complete and incomplete) and dislocations (sacroiliac and coxofemoral) in polytraumatized cats and dogs.

MATERIALS AND METHODS

The project was approved by the Ethics Committee on the Use of Animals (CEUA) of the Federal Rural University of the Semi-Arid Region (UFERSA), located in Mossoró, RN, Brazil (5º03′37" S, 37º23′50" W, and 72 m of altitude) under protocol 23091.005025/2018-30. This research was conducted with routine clinical animals of varying ages, breeds, and weights from January to October 2019, with animals that presented suspected pelvic trauma (fractures and/or dislocations) and were sent to the imaging diagnostic sector at the Jerônimo *Dix-Huit* Rosado Maia Veterinary Hospital of UFERSA. The study was conducted with the owner's consent upon signing an authorization form.

The animals were subjected to a sedation protocol with ketamine 3 mg/kg, meperidine 3 mg/kg, and midazolam 0.3 mg/kg intramuscularly, and anesthetic induction with propofol 4 mg/kg intravenously to obtain the radiographs. In all animals, orthogonal projections were performed according to Crawford, Manley and Adams (2003): ventrodorsal (VD) flexed (frog-leg) or extended and left or right laterolateral (LL), or both, depending on the fractured side and condition of the animal and compared with the right and left ventral-45° medial to dorsolateral oblique frog leg ("rollover 45-degree view") (STIEGER-VANEGAS et al., 2015). The animals were subjected to radiographic imaging using a fixed 500mA x-ray device (XRAD®, São Paulo - SP) and digitized on a direct digital storage plate (PIXXGEN®, Flat panel Digital X-ray detector, model PIXX1417, South Korea) using 50–80 Kvp, 200mA, and 2–5 mAs.

After obtaining the radiographs, they were evaluated for the lines (quantification) and location (qualification) of the fractures. Four groups of evaluators performed the evaluations, consisting of two radiologists (RAD) as the control group, two orthopedists (ORTO), two diagnostic imaging residents (RESRAD), and two students (STUDENT) in the fifth year of Veterinary Medicine who had already taken the Imaging Diagnosis discipline. All evaluators were placed in a room where the radiographic images were presented to them through individual computers with DICOM (Digital Imaging and Communications in Medicine) image viewers, distributed randomly, and the evaluators did not know the animals. Each image was evaluated by the presence or absence of fractures and dislocations for up to 5 minutes each (STIEGER-VANEGAS et al., 2015).

The total number of complete and incomplete fractures and sacroiliac and coxofemoral dislocations visualized between the VD, LL, and OBL projections was compared. Furthermore, intra-observer radiographic diagnoses were compared. A comparison of means for non-parametric data was conducted using a GLM considering the WALD statistical test and $p<0.05$. The most affected pelvic bone was also evaluated by comparing means using the X2 ranking test. For this purpose, the statistical software IBM SPSS Statistics V22.0 was used.

RESULTS AND DISCUSSION

The average age of animals presented was 1.8 years old. It corroborates previous trauma studies that found animals to be younger (RODRIGUEZ et al., 2021; FLORES et al., 2023). Older cats were more sedentary and assumed to present a lower risk of being involved in road accidents and other trauma (HAINE et al., 2019). Most animals (83%) in the present study were male (Table 1), following other studies (HAINE et al., 2019; RODRIGUEZ et al., 2021; FLORES et al., 2023). The most frequent fracture cause in the present study was trauma resulting from a road traffic accident with multiple lines of fracture (BOOKBINDER; FLANDERS, 1992; MEESON; GEDDES, 2017), with male cats being more prevalent. Female cats were more involved in high-rise syndrome. (ZULAUF et al., 2008). Most pelvic fractures originate from automobile accidents or falls (Table 1) (ROEHSIG et al., 2008; BRUCE; BRISSON; GYSELINCK, 2008; KEMPER et al., 2011), with 83% (10/12) of cases having this origin in our study, and dogs suffering more trauma when compared to cats (SCOTT; McLAUGHLIN, 2007). However, the greater number of felines, 67% (8/12), makes this study interesting, probably due to the increase in the population of semi-domiciled domestic felines (SCOTT; McLAUGHLIN, 2007). All cats admitted to this study had access to the street, which made them more prone to trauma, corroborating the findings cited by Kipfer and Montavon (2011).

Table 1. Radiographs of twelve animals with pelvic trauma were evaluated.

Animal*	Species	Age	Sex	Trauma
1	Feline	Mature	Male	Road traffic accident
2	Feline	Immature	Male	Road traffic accident
3	Feline	Immature	Male	Road traffic accident
4	Feline	Mature	Male	Road traffic accident
5	Feline	Mature	Male	Road traffic accident
6	Feline	Mature	Male	Road traffic accident
7	Feline	Mature	Male	Road traffic accident
8	Feline	Immature	Female	Road traffic accident
9	Canine	Mature	Female	Not informed
10	Canine	Immature	Male	Falling
11	Canine	Mature	Male	Road traffic accident
12	Canine	Mature	Male	Road traffic accident

*All animals were spayed.

Regarding sex, males were more prevalent than females, with 83% (10/12) and 17% (2/12), respectively, as verified by Souza et al. (2011) When evaluating dogs and cats, they suggest that unneutered males access the streets mainly in search of females in heat, thus becoming more susceptible to being run over or fighting. Generally, pelvic fractures are multiple, in which three or more bones are involved and are rarely exposed (CRAWFORD; MANLEY; ADAMS, 2003; PIERMATTEI; FLO, 2006), corroborating our study where the animals evaluated presented compound fractures, and none were exposed. This probably occurred because the lining of the pelvis is made up of large muscle groups and has a rectangular shape (HARASEN, 2007; KEMPER et al., 2011), differing from humans where the fracture can be exposed in a car accident (HENRY, 2013).

The body of the ilium is usually the most affected bone (HARASEN, 2007; SCOTT; McLAUGHLIN, 2007). However, in our study, no significant differences were seen (N= 24, df=2, p= 0.152) between the bones. Despite this, the most fractured region was the pubis ($\bar{x}$ =0.83±0.76), followed by the ischium ($\bar{x}$ =0.79±0.83), and, finally, the ilium ($\bar{x}$ =0.45 ±0.59). In cats, the acetabulum was the most affected part of the pelvis with PADS (RODRIGUEZ et al., 2021), followed by the ischium, ilium, and pubis. Our study is in accordance with Bookbinder and Flanders (1992). They demonstrated that, in traumatic feline pelvic fractures, the pelvic floor was the most affected, with 72% pubic fractures, and the least commonly affected bone was the acetabulum (26%). However, most ischial fractures do not require surgical treatment, and surgical correction is only necessary when the injuries are in the weight-bearing areas or areas of the pelvis, such as the sacroiliac joint, the acetabulum, and the body of the ilium (HAINE et al., 2019.

In the clinical routine for the evaluation of pelvic fractures in dogs and cats, the study commonly begins with VD and LL views (MEESON; CORR, 2011; MEESON; GEDDES, 2017), while OBL views are performed to try to remove bone overlaps to confirm fractures (HENRY, 2013; MEESON; CORR, 2011) and are not included in the routine. However, when comparing the total number of complete and incomplete fractures regardless of the observer (Table 2), VD was the most sensitive compared to OBL) and LL, thus observing a statistical difference between the three views (N=288, df= 2, wald= 24.7, p= 0.0000), between VD and OBL (N=288, df= 2, wald= 11.9, p=0.0005), and between LL and OBL (N=288, df= 2, wald = 24.0, p= 0.000001). However, Stieger-Vanegas et al. (2015) reported that, in dogs, in addition to conventional views (VD and LL), additional studies with OBL views (rollover 45-degree view) are necessary to evaluate pelvic fractures.

Table 2. Complete and incomplete fractures in the VD, LL, and OBL projections.

Views	Total of fractures	Mean	Standard deviation
VD	188	1.95[a]	1.65
OBL	174	1.81[a]	1.17
LL	105	1.09[c]	1.00

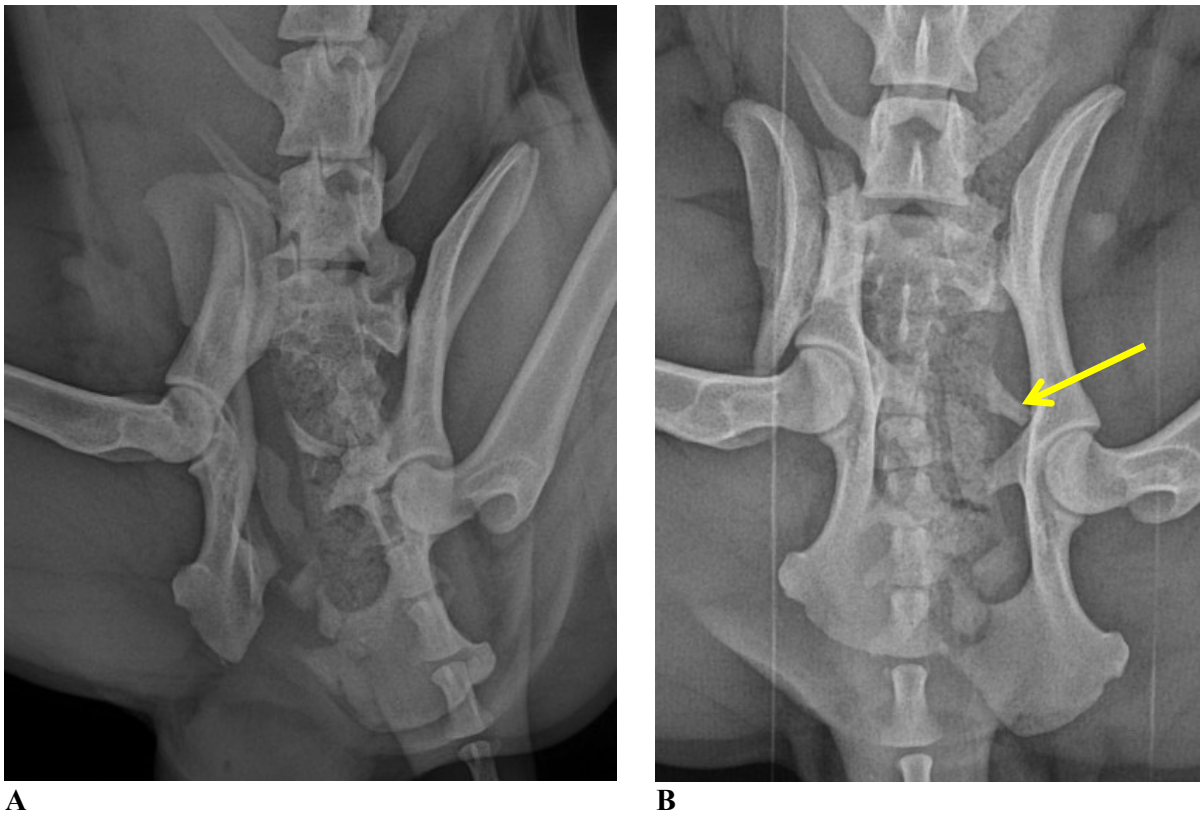
Means followed by the same lowercase letter in the column do not differ.

In the intra-observer comparison, it was impossible to observe a significant difference in the assessment of fractures (N=288, df=3, Wald= 2.3, p=0.5), with the RAD group observing more injuries than RES and STUDENT recognizing what Stieger-Vanegas et al. (2015) described, where radiologists were more accurate in detecting pelvic fractures.

In Table 3, although statistics do not prove radiologists' accuracy, this group observed the most injuries. Another important information in both Tables 2 and 3, when evaluating the pelvis as a whole structure, the VD projection found more lesions; however, the OBL view detected a number of lesions close to found in the VD, and it was only in the hemipelvis, demonstrating its importance in remove overlaps and detect fractures that were not observed in the VD, as can be seen in Figure 1.

Table 3. Total intra-observer number of complete and incomplete fractures.

Group	Views	Total of fractures	Mean	Standard deviation
Radiologists	VD	51	2.12	1.54
	OBL	49	2.04	1.16
	LL	30	1.25	1.07
Orthopedists	VD	37	1.54	0.83
	OBL	43	1.79	1.17
	LL	29	1.20	0.97
Diagnostic imaging residents	VD	51	2.12	1.42
	OBL	41	1.70	1.39
	LL	25	1.04	1.08
Students in veterinary medicine	VD	49	2.04	2.44
	OBL	41	1.70	0.95
	LL	21	0.87	0.89



A **B**

Figure 1. In Image A, a ventrodorsal (VD) projection of a 1-year-old male dog reveals a polytraumatized pelvis; however, due to bone overlap, a fracture in the cranial branch of the pubis could not be confirmed. In Figure 1B, a left oblique (OBL) projection clearly reveals the fracture (yellow arrow), which was not visible in the VD projection (Image A).

However, when evaluating incomplete fractures, discrepancies were found between observers. Considering the RAD group (Table 4) as control, the STUDENT and RESRAD (Diagnostic imaging residents) groups had a significantly higher average number of fractures (N= 288, df=3, Wald= 5.1, p=0.02, and N= 288, df=3, Wald= 4.04, p=0.04, respectively). Furthermore, the ORTO observed fewer incomplete fractures than the control group (N= 288, df=3, Wald= 5.47, p=0.02). This result does not mean radiologists are less sensitive in the assessment because they are the control group. Nonetheless, the STUDENT and RESRAD groups may have committed more errors (extrapolation or overestimation) regarding fractures due to 30% of the animals being puppies and still having growth lines that could have been mistaken for fractures. Stieger-Vanegas et al. (2015) also observed differences between the evaluators in the group of students and surgeons, in which one of the evaluators in each group had a higher error rate than the other when diagnosing pelvic fractures. They also reported that radiologists and surgeons performed similarly (84% and 83%) and were more accurate than students (75%). However, with the patient in mind, it is worth highlighting the importance of a good relationship between professionals from different areas, both for learning and diagnostic purposes.

Table 4. Total number of incomplete fractures identified in the VD, LL, and OBL projections across groups.

Group	Views	Total of fractures	Mean	Standard deviation
Radiologists	VD	3	0.12	0.33
	OBL	4	0.16	0.38
	LL	1	0.04	0.20
Orthopedists	VD	1	0.04	0.20
	OBL	0	0.00	0.00
	LL	0	0.00	0.00
Diagnostic imaging residents	VD	6	0.25	0.53
	OBL	7	0.29	0.62
	LL	0	0.00	0.00
Students in veterinary medicine	VD	10	0.41	1.83
	OBL	1	0.04	0.20
	LL	1	0.04	0.20

Regarding the diagnosis of sacroiliac dislocations, there was no significant difference in the diagnosis among observers. It was shown that the groups evaluated similarly (N= 288, df=3, Wald= 4.0, p=0.25). It corroborates Stieger-Vanegas et al. (2015), who reported that sacroiliac and coxofemoral dislocation were efficiently evaluated by all groups of evaluators through radiographs or CT. However, it was found that the VD (N= 33, $\bar{x}$ = 0.34, SD 0.47) and OBL (N= 33, $\bar{x}$ = 0.34, SD 0.47) views were more efficient than LL (N= 0, $\bar{x}$ = 0.00, SD 0.00) (N= 288, df=2, Wald= 1964.2, P<0.01–10) since, through LL, no dislocations were observed. As for the diagnosis of hip dislocations, all projections were equivalent, with all groups of observers being able to identify the lesion (N= 288, df=3, Wald= 0.71, p= 0.87 for observers, and N= 288, df=2, Wald= 0.86, p=0.86 for views). We suggest that this should have occurred because hip dislocation is easily visible and simple to observe, and LL is important for evaluating the direction of the dislocation (PIERMATTEI; FLO, 2006).

In general, abnormalities (fractures and dislocations) (Table 5) were seen with greater accuracy in the VD view, followed by the OBL (N= 288, df=2, Wald= 18.1, p=0.00002) and LL (df=2, Wald= 40.2, P<0.01–10) views, suggesting that the LL view has less sensitivity in assessing pelvic abnormalities in polytraumatized dogs and cats. However, it is suggested that OBL views are included in pelvis studies, especially in felines, which comprised the majority of the study (66%), whereas the LL view is performed in cases of targeting coxofemoral dislocations. These results corroborate Stieger-Vanegas et al. (2015), who stated that OBL radiographs can aid in accurately diagnosing pelvic fractures in dogs when CT is unavailable. Furthermore, OBL projections allow the animal's hind limbs to remain abducted without tension, thus reducing the pain caused by handling the patient.

A limitation of the study was the non-performance of CT. Still, it is not universally available, and high-quality radiographs are possible when CT is unavailable. In complicated fractures visualized in radiographs, the CT provides multi-plane reconstruction and three-dimensional visualization of fragments, allowing more accurate surgical planning in pelvic fractures in cats (DRAFFEN et al., 2009; HAINE et al., 2019). Although there is no statistical difference, mainly between the VD and OBL views, we know that the OBL observed injuries that the VD view did not, and this was another limitation of the study, in which we did not describe where these fractures were, despite knowing that all of these fractures observed were possibly in the acetabulum topography, which is where the OBL view removes the overlaps.

Table 5. Total number of abnormalities (fractures and dislocations) in the VD, LL, and OBL views.

Views	Total of fractures	Mean	Standard deviation
VD	237	2.46[a]	1.80
OBL	225	2.34[b]	1.35
LL	120	1.25[a]	1.04

Means followed by the same lowercase letter in the column do not differ.

CONCLUSION

Currently, four views are suggested when evaluating the pelvis in dogs. After quantifying and qualifying the abnormalities found in the pelvis of the animals in our study, we reinforce the importance of including the OBL view in radiographs with suspected changes in the pelvis in felines, as it decreases the overlaps between structures. The VD and OBL views have demonstrated their effectiveness in diagnosing fractures and dislocations in the pelvis of dogs and cats. Although radiologists are more sensitive in diagnosing abnormalities in the pelvis, the study did not demonstrate a statistical difference between evaluators, possibly due to the error rate of other groups.

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