Power Doppler sonography in the assessment of neovascularization following surgical fracture repair in sheep: case report

Utilização da ultrassonografia Power Doppler *no acompanhamento de neovascularização no pós-operatório de ovino submetido a osteossíntese: relato de caso*

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Abstract

Sonography is a safe and non-invasive imaging modality, with the added benefit of providing dynamic images. Power Doppler sonography allows blood vessel identification regardless of flow intensity or direction. A one-year-old Ile de France ewe was admitted to the FMVZ-USP Veterinary Hospital with a complete tibial fracture. The animal was submitted to general inhalation anesthesia and fracture repair using a 3.5 mm locking compression plate. Power Doppler sonography was used to assess neovascularization over the course of the bone healing process. Formation of new vessels was noted between postoperative days 14 and 21; new vessels regressed progressively on subsequent assessments (postoperative days 28 and 35). Power Doppler sonography enabled early detection of newly formed blood vessels at the fracture site. The non-invasive nature of this imaging modality prevented patient stress and provided useful information on the progression of bone healing. Early neovascularization was thought to reflect successful postoperative healing of the tibial fracture described.

Keywords: Neovascularization. Ovine. Osteosynthesis. Power Doppler.

Resumo

A ultrassonografia é técnica de imagem segura e não invasiva que fornece imagens dinâmicas. O *Power Doppler* é modalidade ultrassonográfica que permite a visualização de vasos sanguíneos sem depender de intensidade e direção de fluxo. Admitiu-se no Hospital Veterinário da FMVZ-USP um ovino fêmea, de raça Ile de France, com um ano de idade e apresentando fratura completa de tíbia em bisel. O animal foi submetido à anestesia inalatória para a realização de osteossíntese com placa bloqueada de 3,5 mm. Durante o período pós-operatório foram realizadas imagens de ultrassonografia *Power Doppler* para a avaliação da neovascularização ao longo do processo de regeneração óssea. Entre o 14º e o 21º dia do período pós-operatório, identificou-se a presença de vasos sanguíneos neoformados, que apresentaram sinais de regressão nas avaliações subsequentes (realizadas no 28º e no 35º dia pós-operatório). A ultrassonografia *Power Doppler* mostrou-se eficiente na detecção precoce de vasos sanguíneos neoformados na região da fratura no período pós-operatório, sendo um exame não invasivo, que não gerou estresse para o animal e que pode estar relacionado ao sucesso no reparo ósseo da tíbia do animal submetido à osteossíntese.

Palavras-chave: Neovascularização. Ovino. Osteossíntese. Power Doppler.

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Received: 24/08/2016
Approved: 27/07/2017

Literature Review

Traumatic injuries trigger vascular reactions in response to vessel wall rupture, leading to escape of fluids, proteins, and blood cells at the site of injury. As a consequence, a complex process of new vessel formation occurs to promote local oxygen and nutrient delivery. This process, referred to as angiogenesis, is a key component of bone healing and is regulated by molecular signals mediated by growth factors such as fibroblast growth factor (FGF), transforming growth factor (TGF-β), and platelet-derived growth factor (PDGF) (CARVALHO, 2008).

Monitoring of fractures is vital to assess complications and bone regeneration. New vessels are known to form and then regress over the course of the fracture healing process. Power Doppler imaging is indicated to evaluate this process, given other methods, such as scintigraphy and intraosseous venography, are invasive and require general anesthesia (RISSELADA et al., 2006).

Fractures are known to disrupt local blood supply. Bone vascularization is a prerequisite for proper bone healing; therefore, if blood flow cannot be restored, delayed healing or fracture nonunion may result (CHEUNG et al., 2012). Assessment of neovascularization contributes to early recognition of fracture union or nonunion (RISSELADA et al., 2006).

The strength of the Doppler signal in color reflects the number of moving blood cells rather than speed. Also, this tool is less dependent upon angle of insonation (NYLAND; MATTOON, 1995).

Given the high sensitivity of Power Doppler in detecting blood flow and its ability to clearly depict vessel boundaries, this imaging modality offers some advantages over color Doppler, particularly where small vessels, vessels with decreased blood flow, vessels coursing at unfavorable insonation angles, or vessel branches are concerned (MARTINOLI et al., 1998).

In human medicine D'Agostino et al. (2003) demonstrated Power Doppler possibilities of detecting abnormal vascularity in most cases of spondylar arthropathy. These findings first detected cortical bone cartilage insertion and in lower intensity at the calcaneal bursae.

Risselada et al. (2006) described 51 radius and ulna postoperative osteosyntheses comparing minimally invasive technique and open technique. Bone callus formation was followed up with radiography and Power Doppler ultrasound. The minimally invasive group presented larger bone callus formation then the open technique group. There was no statistical differences in neovascularization between both groups. The authors describe vessels in large scale for all evaluated animals.

Case Report

A one-year-old Ile de France ewe was admitted to the FMVZ-USP Veterinary Hospital with a complaint of lameness. The owner reported overt left hind limb lameness and deviation of the affected limb from the longitudinal axis. A bandage was applied, with no resistance on the animal's part.

Figure 1 – Complete tibial fracture in an ewe. Radiographic image obtained immediately after repair with a locking compression plate

Clinical signs upon admission were as follows: apathy, heart rate of 108 bpm, respiratory rate of 48 bpm, rectal temperature of 39.7ºC, hyperemic mucous membranes and normal ruminal motility. Instability of the left pelvic limb at the level of the tibia was noted on palpation; however, the skin was intact.

Radiographic examination revealed a complete oblique fracture at the distal aspect of the left tibia. The animal was submitted to general inhalation anesthesia and fracture repair using a 3.5 mm locking compression bone plate (LCP); seven and three screws were placed proximally and distally to the fracture line respectively (Figure 1). A compression bandage was then applied to the operated limb.

The surgical wound was treated with saline solution and topical rifampicin, and bandages changed daily. Postoperative medication consisted of amikacin (22 mg/kg IV SID for 20 days), benzylpenicillin (40,000 IU/kg IM SID for 10 days), phenylbutazone (4 mg/kg, IV, SID for 6 days), ranitidine hydrochloride (2 mg/kg IV QID for 8 days), and morphine sulphate (0.1 mg/kg IM QID for 10 days).

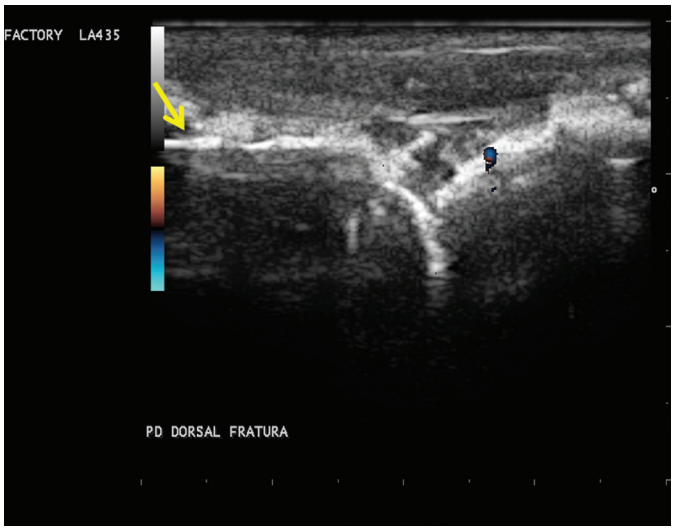

Figure 2 – Complete tibial fracture in an ewe. Power Doppler sonography of the fracture site within 14 days of surgery. Note the presence of blood vessels (arrow)

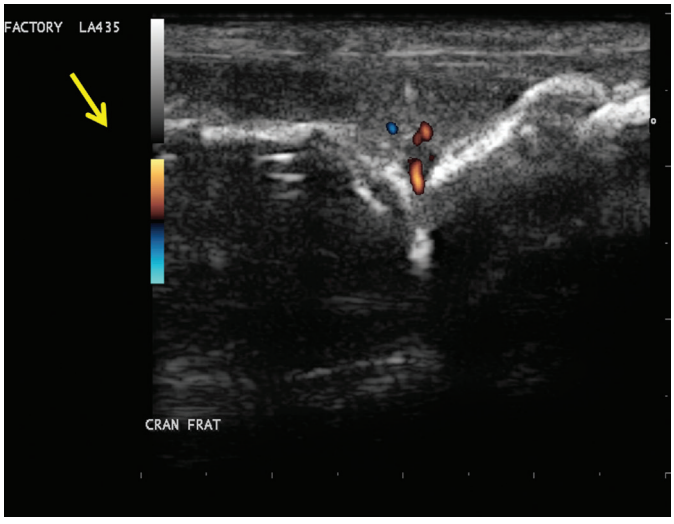

Figure 3 – Complete tibial fracture in an ewe. Power Doppler sonography of the fracture site within 21 days of surgery. Note the presence of a larger number of blood vessels (arrow)

Image-based follow-up assessment consisted of Power Doppler sonography at postoperative days 14, 21, 28, and 35 for investigation of new vessel formation and subsequent bone healing. Blood vessels adjacent to the fracture line were seen on day 14 (Figure 2). Larger numbers of vessels were detected at the fracture site on day 21 (Figure 3), with partial vessel regression on subsequent sonographic assessments.

The animal was discharged from hospital with the LCP in place and a return visit scheduled for plate removal within 60 days of surgery. The owner reported full return to function.

Discussion

Trauma dictates the formation of new vessels required to deliver oxygen and nutrients to the site of injury (CARVALHO, 2008). Power Doppler enabled early detection of postoperative neovascularization in this study, even when only small vessels were present. The ability of Power Doppler to detect small vessels has been reported elsewhere (WAKEFIELD et al., 2003) and reflects the high sensitivity of this imaging modality for identification of vessels with low blood flow.

The first reports of the Power Doppler possibilities were described in human medicine. Several authors describe this ultrasound modality in arthropathies (D'AGOSTINO et al., 2003), which can also be a possibility for other species rather than fracture follow-up.

Detection of neovascularization during the bone healing process is thought to be an excellent sign (RISSELADA et al., 2006). New vessels have been shown to form over the course of the regenerative process, then to regress as healing progresses (RISSELADA et al., 2006). Similar events were documented in the case studied, with clear detection of new blood vessels within 14 and 21 days after surgery, which regressed progressively from day 28.

The relationship between neovascularization and fracture union has been emphasized (RISSELADA et al., 2006; CHEUNG et al., 2012;). The possibility of detecting new vessel formation during the postoperative follow-up of large animals submitted to fracture repair might bring significant contributions, particularly for prognostication.

Risselada et al. (2006) described 51 radius and ulna postoperative osteosyntheses evaluated by Power Doppler ultrasound. The present case has similar results with this previous report, and a large number of vessels were seen.

Power Doppler sonography is indicated for visualization of convoluted vessels and vessels with low flow (NYLAND; MATOON, 1996). Vessels developing at fracture sites are known to have these features and to regress over the course of the bone healing process; therefore, power Doppler was selected for neovascularization assessment in the case presented.

Conclusion

Power Doppler sonography proved to be a useful, sensitive, and non-invasive tool for postoperative assessment of fracture healing in sheep. Formation of new vessels was thought to be associated with successful bone healing following surgical repair of a tibial fracture in the case described.

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