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Case Report

Vacuum-assisted closure for management of a traumatic neck wound in a horse

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Introduction

Traumatic injuries resulting in substantial soft tissue deficits are common in horses. When primary or delayed-primary closure is not feasible or fails, the wound must heal by second intention. Wound closure and epithelialisation can take many weeks with large wounds and may leave a large scar, perhaps with functional impairment (Stashak 1991).

Vacuum-assisted closure (VAC) is a method of wound therapy that has been used in human plastic and reconstructive surgery for several years. The procedure involves application of subatmospheric pressure (typically 125 mmHg) to the wound either continuously or intermittently (e.g. cycles of 5 mins on/2 mins off) until healing is advanced (Morykwas *et al.* 1997).

Studies in pigs have shown that application of controlled subatmospheric pressure to wounds results in an increase in local tissue blood flow, reduction in oedema at the wound margins, acceleration of granulation tissue formation, and reduction in bacterial numbers in the wound (Morykwas *et al.* 1997). Together, these effects enhance wound healing.

Clinical use in human patients has demonstrated the value of VAC therapy in enhancing the healing of acute, subacute, indolent and infected wounds (Argenta and Morykwas 1997; De Lange *et al.* 2000; Scheufler *et al.* 2000; Wu *et al.* 2000; DeFranzo *et al.* 2001). **This report describes the use of a commercially available VAC therapy system for the treatment of traumatic wounds on the neck of a horse.**

Case details

History

A nine-year-old Arabian gelding was discovered in a wooded pasture with 2 large wounds on the ventrolateral aspects of the neck, in the caudal third of the cervical area (**Figs 1** and **2**). The cause of the injury was not known, although fencing wire or a metal fence stake may have been involved. The wounds were bleeding freely when the horse was found, but first aid (direct pressure then cold hosing) administered by the caretaker provided good haemostasis.

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Clinical findings

On presentation 1 to 2 h after injury, the wound on the left side of the neck measured approximately 21 x 18 cm in area and 8 cm in depth at its deepest point. The left jugular vein was intact but had been dissected from the surrounding tissue for at least 6 cm of its length (**Fig 1**). The trachea and oesophagus were visible in the depths of the wound, but were undamaged.

The wound on the right side of the neck was smaller, measuring approximately 13 x 9 cm in area and 5 cm in depth at its deepest point (**Fig 2**) and no vital structures were exposed. The left and right wounds did not appear to communicate, although they were separated by only a narrow isthmus of tissue. On physical examination, all vital signs were within normal limits.

Treatment

Even at this early juncture, the wound edges could not be apposed without considerable tension. This fact and the location, size and orientation of the wounds made dehiscence of any primary closure and subsequent infection highly likely. Prior experience with VAC therapy in a horse encouraged us to forego primary closure and use VAC therapy to promote healing by second intention.

A wet-to-dry dressing was applied to each wound using saline-soaked gauze, rolled out to accommodate the size of the wound and held in place with a self-adhesive bandage. Tetanus toxoid and oxytetracycline were administered i.m.; phenylbutazone was administered i.v. and dispensed for subsequent oral administration. Oxytetracycline was continued for 5 days, after which time antimicrobial therapy was switched to oral trimethoprim-sulphamethoxazole. The

Fig 1: Appearance of the wound on the left side of the neck 24 h after injury. The left jugular vein has been dissected from the surrounding tissue (arrow) in the depths of the wound. A blood clot hangs from the ventral margin of the wound.

Fig 2: Appearance of the wound on the right side of the neck 24 h after injury. The extent of the tissue defect on the left side of the neck is readily apparent.

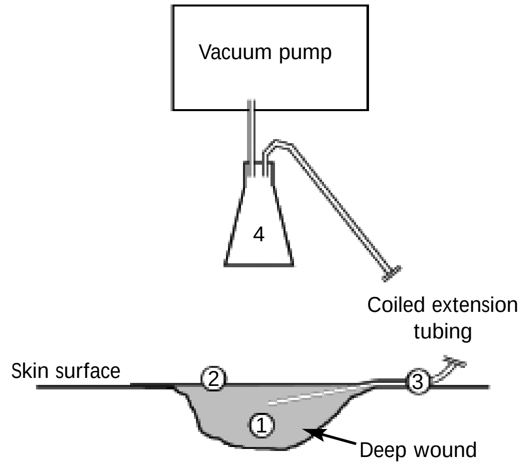

Fig 3: Basic components and configuration of the VAC system. 1 = Polyurethane foam filling the wound cavity; 2 = adhesive barrier drape sealing the wound; 3 = evacuation tube; 4 = flask for collection of fluid aspirated from the wound.

Fig 4: Collapse of the foam dressing and adhesive barrier drape confirms that an airtight seal has been achieved.

horse was confined to a stall and provided with food and water at chest height.

Wound preparation

On the following day the dressings were changed and the wounds inspected. Hair on the skin surrounding each wound was removed using a depilatory cream, leaving a zone of hairless skin at least 8 cm wide around each wound.

This step was necessary to ensure a good seal of the adhesive barrier drape that would be placed over the wound. From prior experience, it is necessary to depilate the skin at least 24 h before application of the VAC system, because the depilatory cream causes an inflammatory response which results in serous discharge from the skin for several hours after application.

On Day 2 post injury the gauze dressings were removed. Each wound was debrided as necessary to remove any devitalised or severely compromised tissue in preparation for application of the VAC system.

Application of the VAC system

The VAC system comprises an open-cell polyurethane foam dressing, an evacuation tube (fenestrated with multiple side ports at the distal end), a waterproof adhesive barrier drape and an adjustable vacuum pump[1]. The dressing consists of a piece (or pieces) of medical-grade, open-cell, polyurethane ether foam with a pore diameter of 400–600 µm, sized and trimmed to fill the wound cavity. A 1 litre flask was added to the system to accommodate the large volumes of fluid that would be collected from the wounds in the first few days. The basic configuration of the VAC system is depicted in **Figure 3**.

The system was further modified by adding a coiled extension set (the type commonly used to administer i.v. fluids

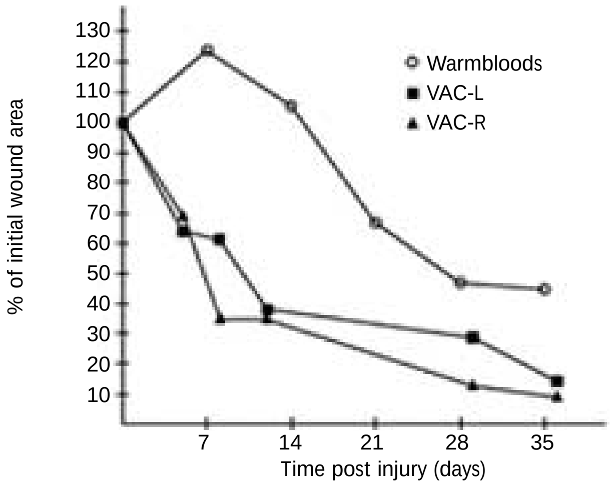

Fig 5: Comparison of the rate of wound healing between the case presented here and a recent study of wound healing in Warmbloods (Wilmink* et al. *1999). VAC-L and VAC-R denote the wounds treated with vacuum-assisted closure on the left and right sides of the neck, respectively.

Fig 6: Appearance of the wound on the left side of the neck on Day 14 post injury.

to large-animal patients) between the evacuation tube and the vacuum pump. Adding this length of coiled tubing allowed the horse to move about the stall for food and water, and even to lie down, without disturbing the VAC system.

Only the tubing portion of the coiled extension set was used; the drip chamber and distal connector were cut off and discarded. Connections were made by heating the cut ends of the extension tubing with a cigarette lighter, dilating the opening with a haemostat, inserting the connecting tube into the dilated end of the extension tubing, then pressing the 2 tubes together over the connection as the tubing cooled. These connections were further secured with adhesive tape to ensure an airtight seal and to minimise the chance of disconnection as the horse moved about the stall.

The vacuum pump was suspended from a roof joist in the centre of the horse's stall using a short length of chain and a swivel hook. The electrical cord for the pump was tied well

Fig 7: Appearance of the wounds (ventrodorsal view) on Day 29 post injury.

Fig 8: Appearance of the wound on the left side of the neck on Day 36 post injury.

Fig 9: Appearance of the wound on the left side of the neck 4 months post injury.

above head height as it crossed the stall to the electrical outlet. The evacuation tube, extension tubing and vacuum pump were made ready for immediate use before the dressing was applied to the wound.

After preparing each wound as described above, a tissue adhesive (Mastisol)[2] was applied to the depilated skin around

TABLE 1: Wound dimensions during the first 5 weeks post injury

Time post injury (days)	Height (cm)	Width (cm)	Depth (cm)	Wound area H x W (cm^2)
Left side				
0*	20.9	17.8	8.3	372.0
5	17.8	13.3	6.4	236.7
8	16.5	11.4	6.4	188.1
12	15.9	8.9	4.4	141.5
29	14.0	7.6	2.5	106.4
36*	10.2	3.8	1.3	38.8
Right side				
0*	12.7	8.9	5.1	113.0
5	10.2	7.6	3.8	77.5
8	8.9	4.4	2.5	39.2
12	8.9	4.4	1.3	39.2
29	7.6	1.9	0	14.4
36*	7.6	1.3	0	9.9

*Measurements on these days are approximations. VAC therapy began on Day 2 and was discontinued on Day 29 post injury.

the wound. Pieces of polyurethane foam were cut to fit and packed into the wound so that the entire wound cavity was filled with the foam material. The fenestrated distal end of the evacuation tube was embedded in the foam in each wound.

As the wounds were separated by only a narrow strip of skin on the ventral aspect of the neck, the wounds were evacuated in series. The evacuation tube ran from the wound on the right side, under the neck, and through the wound on the left side. The nonfenestrated portion of the tube was placed so that it exited the left wound against the skin without making an acute angle.

The adhesive drape, which was several centimetres larger than the area covered by both wounds, was placed over the wounds and pressed firmly against the skin to create an airtight seal around the entire perimeter of each wound. Extra care was taken to form an airtight seal where the evacuation tube exited the wounds. The adhesive drape was wrapped around the tube as it crossed the skin and the adhesive surfaces were pressed together between tube and skin to form a short mesentery for the tube. For added security, duct tape was used to tape the edges of the adhesive drape to the surrounding hair.

As soon as the adhesive drape was in place, the vacuum pump was turned on at a continuous pressure of 125 mmHg. It was important to begin negative pressure as soon as the drape was applied, as it helped to create an airtight seal over the wound. Collapse of the foam and adhesive drape and, after several mins, the presence of serum in the evacuation tube confirmed that an airtight seal had been achieved (**Fig 4**).

The evacuation tube was fastened to the horse's mane just cranial to the withers and a stretch-fabric neck covering[3] was placed over the horse's neck to provide added protection for the wound drapes and tubing. In addition, a wooden neck cradle was used to limit neck flexion.

The horse's owner was instructed in monitoring the system for failure, such as loosening of the adhesive drape (as evidenced by loss of foam compression), kinks in the evacuation or extension tubing, and disruption of any connections. The owner was also instructed in emptying the collection flask as it filled.

Clinical course

The foam dressing was replaced and the wounds evaluated every 3 to 4 days. Wound dimensions were measured on Days 5, 8, 12, 29 and 36 post injury (**Table 1**). As shown in **Figure 5**, wound area decreased rapidly between Days 2 (initiation of VAC therapy) and 5, and continued this rapid reduction in size until Day 12. Reduction in wound area was slower between Days 12 and 29 post injury. Nevertheless, wound areas on Day 29 were 29 and 13% of the initial area on the left and right sides of the neck, respectively.

Wound depth steadily decreased as granulation tissue filled the defect (**Table 1**; **Fig 6**). By Day 29 post injury, granulation tissue filled the wounds sufficiently that VAC therapy could be discontinued (**Fig 7**). Aspiration of fluid from the wounds also steadily decreased during treatment. For the first few days, the 1 litre flask required emptying every 10 to 12 h. By the end of the 29-day treatment period, the flask was not full even after 48 h.

Light physical therapy was begun on Day 8 with short periods of grazing in hand. On Day 14 the owner began using treats to encourage gentle extension of the horse's neck, with the aim of limiting contracture of the damaged cervical muscles as they healed. Light ridden exercise commenced on Day 29 post injury.

Following discontinuation of VAC therapy, wet-to-dry dressings were used to keep the wound surfaces protected until epithelialisation was advanced. The wounds were lavaged with normal saline solution at each dressing change. The owner was instructed to keep the stretch-fabric hood on the horse's neck until epithelialisation of both wounds was complete.

In the week following discontinuation of the VAC system (between Days 29 and 36), the wounds contracted further and the granulation beds became level with the skin surface (**Fig 8**). Skin grafting was offered at this time but was declined by the client. Despite that, the final functional and cosmetic results were considered very good. The horse had normal mobility of the neck, and the amount of scarring was acceptable to the owner (**Fig 9**).

At no time during application of VAC wound therapy or following its discontinuation did the jugular vein, oesophagus or trachea appear to be compromised. Neither jugular vein was distended cranial to the injury site, and the horse showed no signs of respiratory embarrassment or difficulty swallowing.

Discussion

Vacuum-assisted closure greatly facilitated second-intention wound healing in this horse. Subjectively, both wounds healed much more quickly and with less scarring than expected for the size and depth of the tissue deficits. Comparison with a recent study on wound healing in horses confirmed our clinical impression (**Fig 5**).

Wilmink *et al.* (1999) surgically created wounds on the buttocks of a group of Warmblood horses and monitored wound contraction and epithelialisation over the following 12 weeks. The initial wounds were 2.0 x 3.5 cm in area and 1.8 cm in depth, involving skin, subcutis and a portion of the underlying *biceps femoris* muscle. As shown in **Figure 5**, wound area increased in the first week post surgery then decreased relatively rapidly over the next 2 to 3 weeks. Reduction in wound area was slow between Weeks 4 and 9 post surgery. Healing of these small wounds was not complete even at 12 weeks post surgery.

Differences between breed of horse and wound location, size and cause aside, it is apparent that VAC therapy prevented the initial increase in wound area and accelerated the rapid contraction phase noted in the study by Wilmink *et al*. (1999). One explanation for this finding is that negative pressure effectively counters the retractive forces on the wound and may even draw the wound edges closer together.

Wound contraction occurs as the contractive forces exerted by myofibroblasts at the wound margins exceed the retractive forces of the surrounding skin and any inflammatory swelling (oedema) at the periphery or excessive granulation tissue within the wound (Wilmink *et al.* 1999). The negative pressure exerted by the VAC system evidently adds considerably to the contractive forces at the wound margins. In addition, the VAC system actively removes excess interstitial fluid from the adjacent tissues, thereby relieving oedema at the wound periphery (Morykwas *et al.* 1997).

The VAC system also accelerates wound closure by enhancing the rate of granulation tissue formation. By packing the wound with an open-cell foam material, the VAC system applies negative force uniformly to the inner surfaces of the wound. This force is postulated to enhance the rate of granulation tissue formation by increasing local blood flow and upregulating cell proliferation and angiogenesis through application of mechanical stress (Morykwas *et al.* 1997).

Experimental studies in pigs have shown that intermittent application of subatmospheric pressure is superior to continuous application in increasing the rate of granulation tissue formation. In surgically created wounds, continuous negative pressure at 125 mmHg increased the rate of granulation tissue formation by 63% over that in control wounds (treated just with wet-to-moist saline gauze dressings). In comparison, application of intermittent pressure (cycles of 5 mins on/2 mins off) increased the rate of granulation tissue formation by 103% over that in control wounds (Morykwas *et al.* 1997). The authors proposed that, while continuous pressure causes a single mechanical stimulus (greatest at the onset of application), intermittent pressure further upregulates cell proliferation by repeating the stimulus over and over. Unfortunately, the VAC pump we used did not have the option of intermittent pressure; only continuous negative pressure could be applied. Use of one of the newer units, which allow the operator to select an intermittent pressure protocol, may have yielded even better results.

The VAC system further contributes to wound healing by limiting or preventing two important impediments to second-intention wound healing in horses; infection and desiccation (Stashak 1991). The foam dressing and barrier drape protect the wound from dust, flies and other contaminants, and they preserve a moist environment on the wound surface. In addition, the VAC system enhances bacterial clearance from the wound by continuously removing interstitial fluid and by improving blood flow, and therefore oxygenation, in the tissues within and adjacent to the wound (Morykwas *et al.* 1997).

One other practical advantage to using VAC therapy for wounds such as those described here is that wound care is simplified once the system is in place. Dressing changes are required less often and they minimally disrupt the wound surface, causing less discomfort to the patient than most conventional types of dressings.

In many cases, the cost of materials for VAC wound therapy would be greater than for conventional therapy applied for the same length of time. However, the cost differential shrinks considerably, and may even be reversed in some cases, when one considers the duration of treatment required. In this case, and in other cases treated by these authors, VAC wound therapy greatly enhanced wound healing, thereby substantially shortening the duration of treatment and allowing the horse to return to regular activities more quickly than expected for conventional wound care.

Complications of VAC therapy in human patients have been described as relatively few and largely technical (Argenta and Morykwas 1997). They include erosion of the underlying tissue when the evacuation tube is positioned directly over bone or the patient lies on the tube; pain for the first 20 mins after application of negative pressure to acute wounds; and ingrowth of granulation tissue into the foam, with resultant disruption of the surface of the granulation bed and pain during dressing changes. These complications can be overcome by careful positioning of the evacuation tube, use of lower pressures for the first 20 to 30 mins, and frequent dressing changes (every 2 or 3 days for most wounds).

Applying continuous suction to wounds in which blood vessels are exposed is contraindicated in human patients, as there is a potential risk for vessel rupture and subsequent exsanguination if the patient is not monitored closely. In the case reported here, the left jugular vein was exposed for several centimetres in the wound on the left side of the neck. Although we encountered no vascular problems by applying the VAC system directly to this wound, beginning 48 h after injury, in retrospect it might have been a wise precaution to have mobilised sufficient tissue to cover the jugular vein before applying the VAC system.

No complications of any kind were observed with VAC therapy in this case. The horse tolerated the dressings, application of 125 mmHg negative pressure to the wounds, dressing changes and stall confinement very well. We had previously used the VAC system on a horse (also with a neck wound) and have since used it on 2 goats (following hemimastectomy) and another horse (following resection of a large melanoma on the underside of the tail). In all cases, the system was very well tolerated and proved extremely effective in accelerating second-intention wound healing.

In each of these cases, the dressings were changed every 3 or 4 days. Removal of the foam dressing created a small amount of sanguineous oozing from the surface of the granulation bed; however, dressing changes did not appear to cause discomfort in any of these patients. Nevertheless, it may be prudent to change the dressing at intervals of no greater than 3 days, to minimise disruption of the granulation bed and migration of epithelial cells from the wound margins.

Practical difficulties associated with use of the VAC system in large-animal patients have included achieving and maintaining an airtight seal over the wound; dealing with excessive coiling and kinking of the evacuation or extension tubing as the patient moves about the stall; and placing the vacuum pump where it is out of the way yet readily accessible.

Thoroughly depilating the skin surrounding the wound, use of a tissue adhesive between skin and barrier drape, and creation of a short mesentery around the evacuation tube as it exits the wound resolved the first problem. Refinements are still needed, however. The depilatory cream we have been using causes an effusive inflammatory response in the skin, necessitating a delay of at least 24 h between depilation and application of the VAC system. A less reactive means of depilating the surrounding skin would be advantageous. Simply clipping the hair and shaving the skin is inadequate, as hair regrowth compromises the seal between skin and drape before the next dressing change is due.

Extension tube maintenance involves periodically disconnecting the tubing from the evacuation tube or collection flask and unravelling it. Use of a swivel hook for suspending the pump minimises excessive coiling of the tubing. Adding a second coiled extension tube may further minimise problems with the tubing.

Battery-powered VAC units are being developed for use in human patients. These small, portable pumps will be ideal for use in horses, as they can be attached to the horse's body, blanket or harness, thereby resolving the problems of pump placement and extension tube maintenance. Compact and lightweight, these units may even allow the horse to be exercised while the pump is functioning (depending on the nature of the wound).

Until battery-powered units become more widely available, pumps powered from the main electrical supply must be used. We have found that the best way to place these pumps for an ambulatory patient is to suspend the pump from an overhead beam in the centre of the stall using a short length of chain and a swivel hook. The pump is then out of the patient's way, it can rotate 360º or more in either direction as the animal moves about the stall, and it can be reached by the caretaker.

It is important, when suspending the pump in the stall, to support the electrical cord well above head height so that the patient cannot bite or get its head over the cord. At the same time, there must be sufficient laxity in the cord that it will not become disconnected if the pump swings as the horse moves about the stall.

Among the many applications of VAC wound therapy in man, perhaps the most relevant for equine medicine and surgery are facilitation of skin grafting (Argenta and Morykwas 1997; Scheufler *et al.* 2000), management of post operative wound infections (Argenta and Morykwas 1997; de Lange *et al.* 2000), and healing of compromised wounds over exposed tendon, bone, or orthopaedic hardware (Argenta and Morykwas 1997; DeFranzo *et al.* 2001). In addition to enhancing healing of traumatic wounds such as those described in this report, VAC wound therapy has great potential for use in horses.

In summary, vacuum-assisted closure greatly facilitated the management of 2 deep wounds on the neck of this horse. Healing time was substantially shortened, allowing the horse to return to light work 4 weeks post injury, and the functional and cosmetic results were very good. The dressings and subatmospheric pressure applied to the wounds were well tolerated by the horse and had no adverse effects on the wound surfaces nor on the vessels and other exposed structures within the wound. Current developments in VAC technology, such as portable vacuum pumps, make vacuum-assisted closure an exciting alternative to conventional methods of wound management in horses.

Manufacturers' addresses

[1]KCI Medical Ltd., San Antonio, Texas, USA.
[2]Ferndale Laboratories Inc., Ferndale, Michigan, USA.
[3]Sleazy Sleepwear for Horses, Hood River, Oregon, USA.

Acknowledgements

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