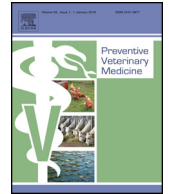




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Hendra virus in Queensland, Australia, during the winter of 2011: Veterinarians on the path to better management strategies



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ABSTRACT

Following the emergence of Hendra virus (HeV), private veterinarians have had to adopt additional infection control strategies to manage this zoonosis. Between 1994 and 2010, seven people became infected with HeV, four fatally. All infected people were at a higher risk of exposure from contact with horses as they were either veterinary personnel, assisting veterinarians, or working in the horse industry. The management of emerging zoonoses is best approached from a One Health perspective as it benefits biosecurity as well as a public health, including the health of those most at risk, in this case private veterinarians. In 2011 we conducted a cross-sectional study of private veterinarians registered in Queensland and providing veterinary services to horses. The aim of this study was to gauge if participants had adopted recommendations for improved infection control, including the use of personal protective equipment (PPE), and the development of HeV specific management strategies during the winter of 2011. A majority of participants worked in practices that had a formal HeV management plan, mostly based on the perusal of official guidelines and an HeV field kit. The use of PPE increased as the health status of an equine patient decreased, demonstrating that many participants evaluated the risk of exposure to HeV appropriately; while others remained at risk of HeV infection by not using the appropriate PPE even when attending a sick horse. This study took place after Biosecurity Queensland had sent a comprehensive package about HeV management to all private veterinarians working in Queensland. However, those who had previous HeV experience through the management of suspected cases or had attended a HeV specific professional education programme in the previous 12 months were more likely to use PPE than those who had not. This may indicate that for private veterinarians in Queensland personal experience and face-to-face professional education sessions may be more effective in the improvement of HeV management than passive education via information packages. The role of different education pathways in the sustainable adoption of veterinary infection control measures should be further investigated.

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1. Introduction

Three quarters of all emerging infectious diseases are zoonoses; diseases that are transmissible between vertebrate animals and humans (Taylor et al., 2001). The management of such diseases usually benefits from a One Health multidisciplinary approach as it requires the collaboration of veterinary and medical professionals to mitigate biosecurity and public health risks. Many zoonoses have been known for decades or even centuries (e.g., Q fever, brucellosis, leptospirosis, salmonellosis) while others have only been recently recognised (emerging zoonotic diseases). Some emerging zoonoses spill over into humans and progress no further. Others spill over and succeed in making the next transition into human-to-human dissemination, becoming a major threat to human health (e.g., Human Immunodeficiency Virus (HIV), Severe Acute Respiratory Syndrome (SARS), swine influenza H1N12009, Ebola virus). Although some of the emerging zoonoses that remain confined to the first generation of human victims have a low-incidence, they remain a public health threat because of the severity of their pathogenicity in humans (Belay and Monroe, 2014). Hendra virus (HeV) is a good example of such a zoonosis. It emerged in humans in Australia in 1993 after spilling over from flying foxes (*Pteropus* spp.) to horses to humans (Murray et al., 1995a,b; Halpin et al., 2000, 2011). Since its emergence it has remained a uniquely Australian zoonosis where 49 equine outbreaks have occurred on the eastern coast between Far North Queensland (QLD) and Northern New South Wales (Department of Agriculture, Fisheries and Forestry Queensland (DAFF QLD), 2014). During this time, 91 horses have been suspected of HeV infection, 71 of which were confirmed positive; while only seven people have been infected (Murray et al., 1995a,b; O'Sullivan et al., 1997; Hanna et al., 2006; Field et al., 2010; Playford et al., 2010; Mahalingam et al., 2012; DAFF QLD, 2014). Compared to pandemic Influenza and SARS, HeV could be considered a minor threat to public health. However, HeV has a 57.1% case fatality rate in humans and all four who died of HeV had professional or direct caring roles for the ill horses. Two were equine veterinarians, one was a person assisting a veterinarian during a horse necropsy, and one was a horse trainer. Another veterinarian, a veterinary nurse, and a stable hand also became infected with HeV but survived. Those who became infected with HeV, did so through close exposure to infectious blood and/or other bodily fluids such as respiratory secretions from an infected horse (Animal Health Australia (AHA), 2013; DAFF QLD, 2014). Currently there is no cure available for those who become infected with HeV. A human monoclonal antibody has been shown to neutralise HeV in primates and has been used as experimental prophylaxis in humans but it is not currently licenced or available commercially (Bossart et al., 2011).

Consequently public health, biosecurity and occupational health and safety government authorities primarily targeted their HeV preventative recommendations to equine veterinarians and their staff. In 2010, all private veterinarians registered with the [Veterinary Surgeons Board of Queensland](#) (VSBQ) received a comprehensive information package about HeV and its management (DAFF

QLD, 2010). Up until 2011, the prevention of HeV was solely based on avoiding exposure, through contact with horses potentially infected with the virus, by implementing adequate infection control (IC) measures such as following hygiene and quarantine protocols and the use of personal protective equipment (PPE). In October 2012 a new HeV vaccine for horses was also released and promoted as a One Health measure that would protect both horses and the people coming into contact with horses, and in particular horse owners and veterinary personnel (Pallister et al., 2011a,b; AHA, 2013; Middleton et al., 2014). However, after more than a year in circulation the vaccine uptake seems to have been moderate despite the initial motivation of veterinarians to encourage horse owners to vaccinate their horses (Mendez et al., 2013a; Department of Primary Industries New South Wales (DPI NSW), 2013). Veterinary IC therefore remains a major component of the management of HeV in private practices providing equine veterinary services.

In the winter of 2011, as part of a cross-sectional study of private veterinarians registered in QLD we investigated: HeV management strategies implemented by eligible veterinarians including their use of PPE, with the aim of identifying the strategies implemented by private veterinarians who treated horses; and to determine if they modified their use of PPE depending on the health status of their equine patients.

2. Methods

2.1. Study design

This study was conducted as a cross-sectional study of private veterinarians providing equine services in QLD, Australia. Eligibility criteria for participation were as follows: (1) being a qualified veterinarian; (2) being registered in QLD; (3) working in private practice in QLD; and (4) to have provided veterinary services to at least one horse in the previous 12 months. All private veterinarians registered with the [Veterinary Surgeons Board of Queensland](#) (VSBQ) and working in private veterinary practices in QLD were invited to participate and self-select as providers of veterinary services to horses. Participation was voluntary and participants could withdraw from the study at any time. This study was conducted with the approval of the James Cook University Human Ethics Committee (Ethics Approval No. H3687).

2.2. Questionnaire design

The questionnaire used for this study was based on the results from a previous qualitative study which explored the HeV-risk related perceptions and barriers to IC and HeV management in equine veterinary practices in QLD between 2009 and 2010 (Mendez et al., 2012a,b, 2013b). The questionnaire also took into account the HeV management recommendations and Workplace Health and Safety (WHS) regulations in place at the time of the study design (DAFF QLD 2010; [Workplace Health and Safety Queensland](#) (WHS QLD); 2011a). The questionnaire was piloted with 6

eligible veterinarians within the target population prior to its implementation.

The questionnaire comprised of a number of socio-demographic, professional and practice profile questions and a number of multiple choice and open-ended questions on the topics of HeV management: management plan; IC facilities in the veterinary practice; HeV field kit; and HeV risk communication with clients. Participants' geographic locations within QLD were categorised according to their postcodes into two regions: Brisbane and Moreton, and other; and five Accessibility/Remoteness Index of Australia (ARIA) categories: highly accessible, accessible, moderately accessible, remote, and very remote. ARIA categories are based on the road distance from the closest service centres (Australian Institute of Health and Welfare, 2004). Moreover, participants were asked how often they used PPE depending on the health status of a horse: a healthy horse (HH); a sick horse (SH); or when they were conducting a necropsy on a dead horse (NH). Participants were also asked to detail which items of PPE they used in each of the different horse health scenarios as well as in the case a horse was suspected to be infected with HeV (HeVH). Participants could choose PPE items from 9 different types of PPE: body (overalls, gown or apron), head (hat), feet (gumboots or boot covers), oro-nasal only (surgical mask, surgical mask with fluid barrier or particulate mask [N95/P2]), oro-nasal and ocular (surgical mask with eye shield or face shield), ocular only (goggles), hand (gloves or arm length gloves) PPE; dressing to cover open wounds or skin abrasions; and powered air respirator (PAR). For each scenario respondents scored one point for each type of PPE they used.

2.3. Questionnaire implementation

The questionnaire was first mailed out in June 2011 to 1604 veterinarians registered with the VSBQ and who were identified as working in private practice in QLD. Three reminders were subsequently mailed out in July, August and September 2011. Each mail out contained an information page, the questionnaire and a pre-paid envelope to return participants' responses. All responses were de-identified upon reception.

2.4. Data management and analysis

Each questionnaire was attributed a unique identification number and responses were collated in Excel (Microsoft, Released 2010) before being transferred into SPSS (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.) for analysis. Categorical data were reported using percentages. Numerical data were reported using mean and standard deviations (SD) when symmetrical, and median and interquartile range (IQR) when skewed. Participants who "always or sometimes" used PPE in a range of scenarios related to the health status of horses were compared to those who used PPE "less often" using Pearson's Chi-square, Chi-square for trend, and Fisher's exact test. Participants' PPE usage score according to the health status of horses were compared using a Friedman's test. Participants with a PPE usage score

above or equal to the median score in a range of scenarios related to the health status of horses were also compared to those who scored below the median score using Pearson's Chi-square. Bivariate analyses were conducted with respect to socio-demographic, practice, professional and HeV experience characteristics. The assumptions for these statistical tests were met. An alpha level of 0.05 was used for all statistical analyses.

3. Results

The socio-demographic, professional and HeV experience characteristics of 204 respondents have been presented elsewhere (Mendez et al., 2013a). However 4 participants, who answered the questions about HeV vaccination for horses in Mendez et al. (2013a), were excluded from the present data analysis as they did not answer the questions about HeV management or were in fact ineligible because they had retired from private practice. Additionally, not all participants answered all questions.

3.1. Socio-demographic and veterinary education (Table 1)

Of the 200 respondents, 96 were male (48%); 116 were 40 years or younger (58%); 156 (78%) graduated from a QLD University. Overall, 70 (34.3%) worked in the Brisbane and Moreton region and 87 (43.5%) were from highly accessible to accessible ARIA (Australian Institute of Health and Welfare, 2004).

3.2. Professional, veterinary practice and HeV management experience (Table 2)

The majority of the respondents worked full-time (89.5%) in mixed practice (79.3%) and provided equine services at least once a week (77.4%) to mostly hobby farms (82.4%) and farms (77.9%) and pony clubs (51.8%). Sixty-six percent had experience dealing with horses potentially infected with HeV. However, only 38.5% had attended an IC/HeV management training session in the previous 12 months. The procedures mostly performed on horses involved: wound management (97.9%), the oro-nasal area (71.6%) and uro-genital area (57.7%). Less than a fifth of respondents carried out necropsies on horses (17.5%). Of the 124 respondents who answered the questions relating to IC control facilities and equipment available at their practice, most reported to have access to sharp disposal units (95.2%) and more than half had access to an autoclave for equipment sterilisation (67.7%). More than half of those who did not answer these questions did not give any further explanation (45/76), while the others (31/76) explained that they either only saw horses in the field or that their practice was purely ambulatory and therefore did not have any clinical premises. However, all the other IC facilities and equipment were much less available in the practices where respondents worked. For example, only 58.9% of participants reported to have a dedicated hand washing station in the practice; 50.8% had access to a biological waste disposal unit and only 34.7% had a quarantine/isolation stable.

Table 1
Demographic and education characteristics of 200^a participants.

Characteristics	Descriptive statistics: frequencies (relative frequencies) unless otherwise stated
Demographics	
<i>Sex</i>	
Female	104 (52%)
Male	96 (48%)
<i>Age group</i>	
≤40 years	116 (58%)
>40 years	84 (42%)
<i>Geographic region within Queensland (n = 195)</i>	
% Residing in Brisbane and Moreton region	65 (33.3%)
% Residing in all other regions	130 (66.7%)
<i>ARIA categories^b</i>	
Highly accessible–accessible	87 (43.5%)
Moderately accessible	39 (19.5%)
Remote–very remote	74 (37%)
<i>Veterinary education</i>	
<i>Median number of years since graduation</i>	12 yrs (IQR ^c = 23.75) (range = 1–45 yrs)
<i>Graduated from</i>	
Queensland university	156 (78%)
Australian university (not Queensland)	24 (12%)
Overseas	20 (10%)

^a n = 200 unless otherwise stated.

^b ARIA: accessibility/Remoteness Index of Australia (Australian Institute of Health and Welfare, 2004).

^c IQR: interquartile range.

3.3. HeV management strategies implemented in the winter of 2011 (Table 3)

The majority of participants worked in a practice that had a HeV management plan (83.1%) but only 58.1% had an in-house HeV specific set of policies/standards procedures. However, in 71.2% (136/191) of cases the HeV management plan included a set of official guidelines (mostly those provided by the QLD government (80.7%; n=88)) and a dedicated HeV field kit (79.1%; n = 191) (mostly put together in house (63.7%) rather than a commercial kit (30.6%)). Many of the other elements recommended by government authorities were not consistently included in the participants' HeV management plans: 46.6% had a HeV risk assessment plan; 28.4% kept records of HeV training attended by staff; only 22.5% had a HeV case reporting system even though HeV is a notifiable zoonosis (AHA, 2013; DAFF QLD, 2014); 31.9% included information materials about flying foxes for horse owners; and 58.6% included HeV information materials for horse owners. Most HeV field kits contained the following items: PPE for the body (98.3%), the hands (93.9%), the eyes (79.9%) and the feet (74.9%); disinfecting agents (80.4%); sampling

kits (77.7%); and waste disposal equipment (76.5%). Field kits were checked for maintenance if not used in only 50.8%.

3.4. PPE usage according to the health status of horses (Table 4)

The PPE usage score of participants significantly increased when the health status of the horse decreased (n = 169; Friedman test; p < 0.001; not included in Table 4). Less than half of the participants (32.4%) always or sometimes used PPE with a healthy horse (HH); while 84.8% did so with a sick horse (SH) and 85.6% used PPE when conducting a necropsy on a horse (NH). The type of PPE used by participants also varied according to the health status of the horse including when the horse was suspected of HeV (HeVH). The median scores for PPE usage were: 2 (IQR = 2; range 0–7/9) with a HH; 4 (IQR = 3; range 0–8/9) with a SH; 6 (IQR = 3; range 0–9/9) when conducting a necropsy on a horse; and 6 (IQR = 2; range 3–9/9) with a horse suspected of HeV. When dealing with a HeVH, participants mostly used: hand (98.9%), oro-nasal (97.2%), body (96.6%), feet (85.5%) and ocular (70.4%) PPE and only 3.9% used PAR; however these PPE items were much less used with a SH not suspected of HeV (80.6%, 59.7%, 67.9%, 46.9%, 35.7% and 0.5% respectively).

3.5. ARIA categories; IC/HeV management plan, training and experience stratified by usage of PPE according to the health status of the horse (Table 5)

Respondents' usage of PPE did not differ significantly across demographic, professional and practice profiles (data not shown) except for the ARIA regions, IC/HeV management training, access to an in house HeV management plan and having experience with a suspected case of HeV. Of the 64 participants who always or sometimes used PPE when examining a healthy horse, 36 (56.2%) had their practice in a highly accessible or accessible ARIA region compared to 51 of the 134 (38.1%) participants who used PPE less often with a HH (p=0.003). Participants who always or sometimes used PPE with a HH (64/200), a SH (168/198) or a NH (176/184) were more likely to have attended an IC and or HeV training programme in the previous 12 months (53.1%; 42.9%; 39.2% respectively) than those who used PPE less often in these scenarios (32.1%; 16.7%; 0% respectively) (p=0.005; p=0.007; p=0.026 respectively). Similar results were observed with participants who worked in a practice which had a dedicated HeV management plan and those who had experience dealing with potential cases of HeV.

3.6. Gender; education; IC/HeV management training and experience stratified by score PPE usage according to the health status of the horse (Table 6)

Participants' scores of PPE usage according to the horse's health status did not vary significantly with most demographic, professional and practice characteristics (data not

Table 2
Professional, practice and Hendra virus experience characteristics of 200^a participants.

Characteristics	Descriptive statistics: frequencies (relative frequencies) unless otherwise stated
Professional profile	
<i>Work time commitment</i>	
Full-time practicing	179 (89.5%)
Part-time practicing	16 (8%)
Other (locum, semi-retired)	5 (2%)
<i>Mean of number of hours worked per week (n = 195)</i>	47.33 h (SD = 12.86) (range 10–90 h)
<i>Role in the practice (n = 197)</i>	
Principal	75 (38.1%)
Partner/associate	20 (10.2%)
Employee	102 (51.8%)
<i>Frequency of veterinary services provided to horses (n = 199)</i>	
Daily	83 (41.7%)
Weekly	71 (35.7%)
Monthly	27 (13.6%)
Less often (yearly/occasionally or on call/after hours)	18 (9%)
<i>Type of premises visited</i>	
Hobby farm (n = 199)	164 (82.4%)
Farm (n = 199)	155 (77.9%)
Pony club (n = 199)	103 (51.8%)
Performances stables (n = 199)	97 (48.7%)
Artificial insemination centre (n = 199)	45 (22.6%)
Stud (n = 199)	72 (36.2%)
<i>Type of procedures regularly performed on horses</i>	
Procedures in oro-nasal area (n = 194)	139 (71.6%)
Procedures in uro-genital area (n = 194)	112 (57.7%)
Necropsy (n = 194)	34 (17.5%)
Wound management (n = 194)	190 (97.9%)
Practice profile	
<i>Practice type (n = 198)</i>	
Large animals only	34 (17.2%)
Mixed	157 (79.3%)
Other (specialised clinics)	7 (3.5%)
<i>Available IC related equipment and facilities in the practice (n = 124)</i>	
Hand washing station (n = 124)	73 (58.9%)
Equipment washing station (n = 124)	54 (43.5%)
Food/beverage exclusion zone (n = 124)	34 (27.4%)
Fridges for food and drugs kept separately (n = 124)	88 (71%)
Quarantine isolation stable (n = 124)	43 (34.75%)
Biological waste disposal units (n = 124)	63 (50.8%)
Sharp disposal units (n = 124)	118 (95.2%)
Sterilisation station (n = 124)	84 (67.7%)
Experience with Hendra virus management	
<i>HeV^b experience (n = 197)</i>	
Had dealt with a potential case of Hendra virus	130 (66%)
Had not dealt with potential case of Hendra virus	67 (34%)
<i>HeV^b education preparedness</i>	
Had gone to an IC-HeV ^c workshop in previous 12 months	77 (38.5%)
Had not gone to an IC-HeV ^c workshop in previous 12 months	123 (61.5%)

^a n = 200 unless otherwise stated.

^b HeV: Hendra virus.

^c IC-HeV: infection control-Hendra virus.

shown). However, when examining a HH those who scored above the median score of PPE usage (61/199) were more likely to be male (59%) than those who scored equally or below the median score (43.5%) ($p = 0.043$). When examining a SH, those who scored above the median score for PPE usage (79/196) were more likely to have graduated from a QLD university (86.1%); to have attended IC/HeV management training in the previous 12 months (50.6%); and to have had experience with potentially HeV infected horses (75.6%) than those who scored equally or below the median score (74.4%; 30.8%; 60% respectively) ($p = 0.048$; $p = 0.005$; $p = 0.024$ respectively).

4. Discussion

Overall, the results of this study show that by 2011 participating veterinarians worked, for the most part, in veterinary practices that had adopted IC/HeV management strategies and attitudes in line with government recommendations. The frequency of PPE usage; and the number and types of PPE items used varied with the health status of equine patients: the sicker the horses the more PPE items were used, and more often. However, these trends were not consistently observed across all practices and participating veterinarians. Some participants were still using very little

Table 3
HeV management strategies implemented by 200^a participants during the winter of 2011.

Characteristics	Frequencies (relative frequencies)
HeV ^b management plan in the practice (<i>n</i> = 195)	
Yes	162 (83.1%)
No	27 (13.8%)
Do not know	6 (3.1%)
Content of HeV ^b management plan	
Set of official guidelines (<i>n</i> = 191)	136 (71.2%)
Source of official guidelines (<i>n</i> = 88)	
– QLD government	71 (80.7%)
– AVA/EVA ^c and/or other	17 (19.4%)
In house HeV specific policies/standard procedures (<i>n</i> = 191)	111 (58.1%)
HeV ^c risk assessment plan (<i>n</i> = 191)	89 (46.6%)
Phone triage system for horse patients (<i>n</i> = 191)	86 (45%)
Information sheet about HeV ^b for horse owners (<i>n</i> = 191)	112 (58.6%)
Information sheet about flying foxes for horse owners (<i>n</i> = 191)	61 (31.9%)
HeV ^b specific field kit (<i>n</i> = 191)	151 (79.1%)
Field kit maintenance record keeping system (<i>n</i> = 191)	33 (17.3%)
Staff HeV ^b training record keeping system (<i>n</i> = 191)	54 (28.37%)
HeV ^b case reporting system (<i>n</i> = 191)	43 (22.5%)
HeV ^b related OHS ^d incident reporting system (<i>n</i> = 191)	44 (23%)
Type of field kit (<i>n</i> = 193)	
Kit put together in house	123 (63.7%)
Commercial kit	59 (30.6%)
Do not have one	11 (5.7%)
Content of field kit (<i>n</i> = 178)	
Oro-nasal PPE ^e (<i>n</i> = 178)	68 (38%)
Oro-nasal and ocular PPE ^e (<i>n</i> = 178)	119 (66.5%)
PAR ^f (<i>n</i> = 178)	6 (3.4%)
Ocular PPE ^e (<i>n</i> = 178)	143 (79.9%)
Head PPE ^e (<i>n</i> = 178)	55 (30.7%)
Feet PPE ^e (<i>n</i> = 178)	134 (74.9%)
Body PPE ^e (<i>n</i> = 178)	176 (98.3%)
Hand PPE ^e (<i>n</i> = 178)	168 (93.9%)
Sampling kit (<i>n</i> = 178)	139 (77.7%)
Waste disposal equipment (<i>n</i> = 178)	137 (76.5%)
Disinfecting agents (<i>n</i> = 178)	144 (80.4%)
PPE ^e to dress wounds and skin abrasion (<i>n</i> = 178)	26 (14.5%)
Frequency of field kit maintenance (<i>n</i> = 181)	
Monthly or less	47 (25.9%)
Every 6–12 months	42 (23.2%)
Never if not used	92 (50.8%)

^a *n* = 200 unless otherwise stated.

^b HeV: Hendra virus.

^c AVA/EVA: Australian Veterinary Association/Equine Veterinarians Australia.

^d OHS: occupational health and safety.

^e PPE: personal protective equipment.

^f PAR: powered air respirator.

PPE when attending sick horses presumably because HeV was not suspected. This may indicate that the initial risk perception when attending a horse plays an important role in determining risk mitigation behaviours; in this case the use of sufficient appropriate PPE. Participants' behaviours and attitudes towards the use of PPE was also influenced by other factors: gender; university of graduation; access to a HeV management plan in the practice; attendance at a IC/HeV management plan training session in the previous 12 months; and previous experience dealing with suspected cases of equine HeV.

4.1. HeV management plans

Although a majority of participants worked in practices that had a formal HeV management plan, many only included a set of official guidelines and a HeV field kit. This may be less a reflection on the level of commitment of

equine veterinarians to HeV mitigation than a reflection of the overall IC and zoonoses management strategies in place in these practices. It may also be an indication that IC for the management of HeV is mostly understood by veterinarians as being the usage of PPE. Similar observations were made during the 2009–2010 qualitative study amongst QLD veterinarians. Infection control in veterinary practices across Australia has been shown to be less than optimal even in specialised equine practices where the risk of exposure to HeV is highest (Leggat et al., 2009; WHS QLD, 2011b; Dowd et al., 2013). The present study showed a lack of IC related equipment in veterinary practices providing services to equine patients. However, some participants may have misinterpreted questions on this topic as most worked in mixed practices which may only have had clinical premises for attending to small domestic animals while large animals may have been mostly seen in the field. Furthermore, other HeV management plan items such as “staff

Table 4Personal protective equipment usage characteristics of 200^a participants according to equine patient's status during the winter of 2011.

Characteristics	Descriptive statistics: frequencies (relative frequencies) unless otherwise stated
Usage of PPE ^b according to horse's health status	
<i>If horse is healthy (HH) (n = 198)</i>	
Always	13 (6.6%)
Sometimes	51 (25.8%)
Rarely or never	134 (67.7%)
<i>If horse is sick (SH) (n = 198)</i>	
Always	66 (33.3%)
Sometimes	102 (51.5%)
Rarely or never	30 (15.1%)
<i>If doing a necropsy on a horse (NH) (n = 184)</i>	
Always	146 (79.3%)
Sometimes	30 (16.3%)
Rarely or never	8 (4.4%)
Type of PPE ^b used according to horse's health status	
<i>If horse is healthy (HH)</i>	
Body PPE (n = 199)	90 (45.2%)
Head PPE (n = 199)	86 (43.2%)
Feet PPE (n = 199)	31 (15.6%)
Oro-nasal PPE only (n = 199)	24 (12.1%)
Oro-nasal and eye PPE (n = 199)	6 (3%)
PAR ^c (n = 199)	0
Ocular PPE only (n = 199)	14 (7%)
Hand PPE (n = 199)	72 (36.2%)
Open skin wound/abrasion PPE (n = 199)	46 (23.1%)
Median for PPE usage score if HH (n = 199)	2 (IQR ^d = 2) (range 0–7/9)
<i>If horse is sick (SH)</i>	
Body PPE (n = 196)	133 (67.9%)
Head PPE (n = 196)	92 (46.9%)
Feet PPE (n = 196)	75 (38.3%)
Oro-nasal PPE only (n = 196)	117 (59.7%)
Oro-nasal and eye PPE (n = 196)	36 (18.4%)
PAR ^c (n = 196)	1 (0.5%)
Ocular PPE only (n = 196)	70 (35.7%)
Hand PPE (n = 196)	158 (80.6%)
Open skin wound/abrasion PPE (n = 196)	63 (32.1%)
Median for PPE usage score if SH (n = 196)	4 (IQR ^d = 3) (range 0–8/9)
<i>If carrying out a necropsy on a horse (NH)</i>	
Body PPE (n = 182)	167 (91.8%)
Head PPE (n = 182)	103 (56.6%)
Feet PPE (n = 182)	145 (79.7%)
Oro-nasal PPE only (n = 182)	147 (80.8%)
Oro-nasal and eye PPE (n = 182)	61 (33.5%)
PAR ^c (n = 182)	5 (2.7%)
Ocular PPE only (n = 182)	98 (53.8%)
Hand PPE (n = 182)	175 (96.2%)
Open skin wound/abrasion PPE (n = 182)	81 (44.5%)
Median for PPE usage score if NH (n = 182)	6 (IQR ^d = 3) (range 0–9/9)
<i>If horse is suspected of Hendra virus (HeVH)</i>	
Body PPE (n = 179)	173 (96.6%)
Head PPE (n = 179)	109 (60.9%)
Feet PPE (n = 179)	153 (85.5%)
Oro-nasal PPE only (n = 179)	174 (97.2%)
Oro-nasal and eye PPE (n = 179)	80 (44.7%)
PAR ^c (n = 179)	7 (3.9%)
Ocular PPE only (n = 179)	126 (70.4%)
Hand PPE (n = 179)	177 (98.9%)
Open skin wound/abrasion PPE (n = 179)	88 (49.2%)
Median for PPE usage score if HeVH (n = 179)	6 (IQR ^d = 2) (range 3–9/9)

^a n = 200 unless otherwise stated.^b PPE: personal protective equipment.^c PAR: powered air respirator.^d IQR: interquartile range.

HeV training record keeping system” and “HeV related occupational health and safety reporting system” may not have been regarded as essential to the practical management of a suspected HeV case as they related to WHS

proof of compliance. These items would only be required if a human under WHS veterinary responsibility became exposed to HeV. Compiling and keeping WHS proof of compliance has previously been reported to be burdensome

Table 5

Accessibility/Remoteness Index of Australia (ARIA) categories, infection control (IC) and Hendra virus (HeV) management training, HeV management experience, and HeV management plan characteristics of 200^a participants stratified by usage of personal protective equipment (PPE) according to the health status of the horse.

	Usage of PPE when examining a healthy horse			Usage of PPE when examining a sick horse			Usage of PPE when carrying out a necropsy on a horse		
	Always or sometimes (n = 64)	Less often (n = 134)	p-Value	Always or sometimes (n = 168)	Less often (n = 30)	p-Value	Always or sometimes (n = 176)	Less often (n = 8)	p-Value
<i>ARIA categories</i>									
% Highly accessible – accessible	36 (56.2%)	51 (38.1%)	0.003 [^]	74 (44%)	13 (43.3%)	0.344 [^]	76 (43.2%)	2 (25%)	0.414 [^]
% Moderately accessible	14 (21.9%)	24 (17.9%)		37 (22%)	2 (6.7%)		38 (21.6%)	1 (12.5%)	
% Remote – very remote	14 (21.9%)	59 (44%)		57 (33.9%)	15 (50%)		62 (35.2%)	5 (62.5%)	
<i>IC-HeV training in previous 12 months</i>									
% Attended training in previous 12 months	34 (53.1%)	43 (32.1%)	0.005 [†]	72 (42.9%)	5 (16.7%)	0.007 [†]	69 (39.2%)	0	0.026 [‡]
% Did not attend training in previous 12 months	30 (46.9%)	91 (67.9%)		96 (57.1%)	25 (83.3%)		107 (60.8%)	8 (100%)	
<i>Experience with HeV cases</i>									
% Had dealt with potential HeV case	49 (76.6%)	79 (60.3%)	0.025 [†]	119 (71.7%)	10 (34.5%)	<0.001 [†]	116 (67.1%)	4 (50%)	0.445 [†]
% Had not dealt with potential HeV case	15 (23.4%)	52 (39.7%)		47 (28.3%)	19 (65.5%)		57 (32.9%)	4 (50%)	
<i>HeV management plan in practice</i>									
% Yes	55 (88.7%)	105 (80.2%)	0.007 [‡]	144 (87.8%)	17 (58.6%)	0.001 [‡]	146 (85.4%)	3 (37.5%)	0.003 [‡]
% No	3 (4.8%)	24 (18.3%)		15 (9.1%)	11 (37.9%)		19 (11.1%)	5 (62.5%)	
% Did not know	4 (6.5%)	2 (1.5%)		5 (3%)	1 (3.4%)		6 (3.5%)	0	

Results are from bivariate analysis.

^a Not all participants answered all questions.

[^] p: values relate to Chi square for trend.

[†] p: values relate to Pearson's Chi square.

[‡] p: values relate to Fisher's exact test.

for private veterinary practices to the point that in some cases equine practice was abandoned because the level of liability became too high (Mendez et al., 2012a).

The most used set of official guidelines for the management of HeV was the one made available by Biosecurity QLD (DAFF QLD, 2010). In 2010, all veterinarians registered and practising in QLD received a comprehensive HeV information and recommendations package from Biosecurity QLD (DAFF QLD, 2010); a move well received by the veterinary profession according to a study conducted by the authors in 2009–2010. Results from both these studies confirm that the government's information campaign of private veterinarians reached a large proportion of its target population. However, our study did not evaluate the effectiveness of this campaign on private veterinarians' attitudes and behaviours in regard to HeV management.

4.2. HeV field kits

Most practices had HeV field kits put together in house. Commercial kits may have been harder to source, more expensive or deemed incomplete. Field kits were not regularly maintained unless used, possibly because they were not being used frequently, or because many of the items included in the field kits were in fact of a disposable nature.

Most kits included most items except PPE for head protection; dressings for wound and skin abrasions; and PAR. It is worth noting that the use of PAR, highly recommended by WHS authorities as the best way to avoid exposure to HeV, is still very low in private practice when dealing with horses, including those suspected of HeV. The access to a seemingly complete HeV field kit, however, cannot be equated to the systematic use of the full range of PPE by veterinarians in the field.

4.3. Use of PPE

Not all participating veterinarians reported using the full panoply of recommended PPE systematically with all horses. The unpracticality of PPE in the field was also found to be an issue common to the management of other non-zoonotic infectious diseases such as equine influenza (Schemann et al., 2014). Furthermore, any additional PPE-related costs had to be justifiable to clients as it affected consultation fees. In order to curb the cost barrier, DAFF QLD introduced a PPE rebate programme in July 2012 (DAFF QLD, 2012). However, the effectiveness of this strategy has not been evaluated.

In 2011, when a horse was healthy, male participants were more likely to use more PPE than females. Male

Table 6

Gender, education, infection control (IC) and Hendra virus (HeV) management training, and HeV management experience characteristics of 200^a participants stratified by score personal protective equipment (PPE) usage according to the health status of the horse.

	PPE usage score when examining a healthy horse (median score = 2)			PPE usage score when examining a sick horse (median score = 4)			PPE usage score when carrying out a necropsy (median score = 6)			PPE usage score when examining a horse suspected of Hendra virus (median score = 6)		
	≤Median (n = 138)	>Median (n = 61)	p-Value [†]	≤Median (n = 117)	>Median (n = 79)	p-Value [†]	≤Median (n = 130)	>Median (n = 52)	p-Value [†]	≤Median (n = 110)	>Median (n = 69)	p-Value [†]
<i>Gender</i>												
% Female	78 (56.5%)	25 (41%)	0.043	62 (53%)	40 (50.6%)	0.746	63 (48.5%)	30 (57.7%)	0.260	53 (48.2%)	41 (59.4%)	0.143
% Male	60 (43.5%)	36 (59%)		55 (47%)	39 (49.4%)		67 (51.5%)	22 (42.3%)		57 (51.8%)	28 (40.6%)	
<i>Education</i>												
% Graduated from Uni in QLD	108 (78.3%)	48 (78.7%)	0.946	87 (74.4%)	68 (86.1%)	0.048	103 (79.2%)	39 (75%)	0.534	87 (79.1%)	51 (73.9%)	0.422
% Graduated from Uni not in QLD	30 (21.7%)	13 (21.3%)		30 (25.6%)	11 (13.9%)		27 (20.8%)	13 (25%)		23 (20.9%)	18 (26.1%)	
<i>IC-HeV training in previous 12 months</i>												
% Yes	50 (36.2%)	27 (44.3%)	0.284	36 (30.8%)	40 (50.6%)	0.005	41 (31.5%)	30 (57.7%)	0.001	40 (36.4%)	32 (46.4%)	0.184
% No	88 (63.8%)	34 (55.7%)		81 (69.2%)	39 (49.4%)		89 (68.5%)	22 (42.3%)		70 (63.6%)	37 (53.6%)	
<i>Experience with HeV cases</i>												
% Had dealt with potential HeV case	86 (63.2%)	43 (71.7%)	0.251	69 (60%)	59 (75.6%)	0.024	86 (67.2%)	35 (67.3%)	0.988	82 (75.9%)	42 (61.8%)	0.045
% Had not dealt with potential HeV case	50 (36.8%)	17 (28.3%)		46 (40%)	19 (24.4%)		42 (32.8%)	17 (32.7%)		26 (24.1%)	26 (38.2%)	

^a Not all participants answered all questions. Results are from bivariate analysis.

[†] All p values relate to Pearson's Chi-square.

veterinarians may have been attending to horses more regularly or may have been carrying out more risky procedures than female veterinarians which would explain their different approach to PPE usage in this case. However, this difference in PPE usage by gender was not carried over in the other scenarios with SH, NH and HeVH patients. The number of veterinarians who always or sometimes used PPE and the amount of PPE used by participants increased as the health status of horses deteriorated. It is likely that veterinarians were making PPE choices according to their perceptions and assessments of the infectious risks involved. Risk perception and risk assessment were not the only factors determining PPE usage. Veterinarians in highly accessible and accessible ARIA regions were more likely to use PPE when examining a healthy horse. This may be because most of the highly to accessible ARIA regions were located in the known geographic distribution range of HeV in QLD; i.e., coastal areas between Far North QLD and South East QLD (DAFF QLD, 2014). Veterinarians in less accessible, inland areas may have perceived the risk of being exposed to HeV as low or were less used to take HeV risks into consideration. The use of PPE by these veterinarians may have also been influenced by the different nature of their clientele. Horse owners from the racing industry were reported to react differently to the veterinary use of PPE than horse owners in rural areas (Mendez et al., 2012b). Rural clients often had different cost benefit expectations of veterinary service provided than other clients and/or viewed the systematic use of PPE by veterinarians negatively (Mendez et al., 2012b).

Veterinarians who had graduated from a QLD university were also more likely to have a PPE usage score above the median score when examining a sick horse than participants who had graduated elsewhere. HeV first emerged in QLD and the majority of the outbreaks have since occurred in this state. Thus, QLD graduates may have received more formal and practical education about HeV during their undergraduate studies. This may have changed since 2011. However, if discrepancies were to remain, they potentially could put young graduates from other states at a higher risk of exposure to HeV. Early career veterinarians tend to have more than one employer within the first 2 years after graduation while some do not stay in the state they graduated from (Heath, 2008). Therefore, all veterinary graduates from all Australian states should be equally made aware of potential occupational infectious risks relevant to all parts of the country. As such, undergraduate veterinary curricula should be consistent across all Australian universities.

The usage of PPE also differed between participants who had attended an IC/HeV management training session in the previous 12 months; had access to a dedicated HeV management plan within their practice; had to deal with at least one potential case of HeV and those who had not. Practical HeV management experience in the field and through professional education as well as leadership in HeV management through planning within the practice may have been more effective in improving veterinarians' usage of PPE when attending to equine patients than the broadly targeted government information campaigns. Alternatively, those who had already had experience with HeV or HeV management may have been more receptive to

the government's campaigns and more motivated to implement the appropriate measures. Participants who rarely or never used PPE with healthy horses and had no experience with HeV or had not sought training or management planning may also have thought that the lack of clinical signs in a horse patient was likely to indicate a low risk of HeV exposure. However, experimentally infected horses have been shown to excrete viral particles at least 48 h before the onset of the first clinical signs, but this was not known until 2011 (Marsh et al., 2011).

4.4. Overall state of HeV management by private veterinarians

HeV outbreaks have been occurring sporadically in QLD and Northern New South Wales since 1994 (DAFF QLD, 2014). However, of the 49 outbreaks that have occurred to date, over a third happened in the winter of 2011 (17/49), and more than half of the 2011 outbreaks occurred in QLD (10/17) (DAFF QLD, 2014). Despite this increase in HeV outbreaks there were no cases of human infection during this time. The uncharacteristic higher number of HeV outbreaks in 2011 may have increased the relevance of HeV risk for veterinarians in QLD who in turn adopted HeV management strategies more readily during this time. Their improved management of HeV may also be the result of a better understanding of the HeV related risks and HeV risk mitigation strategies by the veterinary profession; an improved support from government to veterinarians in the field as recommended by the Ombudsman in 2011 (Clarke, 2011; Queensland Government, 2011); and a better collaboration of government authorities with private veterinarians. However, since 2011 the number of outbreaks per year has greatly decreased and motivation to sustain HeV management strategies may have changed.

This study has also shown that participants with some previous HeV experience or with pre-existing vested interest in HeV management were more likely to adopt and maintain HeV management strategies and attitudes. Hence, practical knowledge about HeV risk and risk mitigation appear to act as a stronger motivator than state wide education campaign promoted by Biosecurity QLD. This concurs with studies conducted in human healthcare settings where the role of education in the adoption of IC measures by health professional was not as strong as expected (Ward, 2011). This should be taken into consideration when devising professional education programmes about the management of specific diseases to increase the effectiveness of these programmes.

The introduction of a HeV vaccine for horses in 2012 (Pallister et al., 2011a,b; Middleton et al., 2014) may also have since influenced HeV management by private veterinarians. Private veterinarians in QLD were very favourable to the HeV vaccine for horses prior to its introduction (Mendez et al., 2013a). The HeV vaccine has since been promoted as essential to the prevention of HeV in horses and their carer which may give a false sense of safety to veterinarians as not all horses in QLD and NWS have yet been vaccinated (DPI NSW, 2013). The effect of the HeV vaccine release

on the veterinary profession's commitment to IC for the management of HeV should be evaluated in the future.

4.5. Representativeness, participation rate, limitations and strengths of study

Of the 1604 eligible veterinarians, 200 (12.5%) completed the questions relevant to this part of the study and returned the questionnaire. However, not all participants answered all questions. Although 12.5% may seem a low level of response, this percentage does not represent the true response rate as the total number of private veterinarians providing equine services in QLD and therefore the true response rate could not be calculated. According to the 2009 president of the QLD division of the Australian Veterinary Association, the Equine Veterinarians Association counted 219 members which however did not include all equine veterinarians in the state of QLD (Dr. B. Pott, personal communication). Furthermore, a 2004 study estimated that equine veterinary services were provided by 12% of all Australian veterinarians (Heath, 2004). Assuming these results were also representative of the veterinary population in QLD in 2011, the 200 veterinarians who participated in the present study may in fact represent a high proportion of the total number of veterinarians providing equine services in QLD. Another potential limiting factor to this study was that the private veterinary workforce in QLD had been under high scrutiny from the government in 2010 in relation to IC and HeV management (WHS QLD, 2011b). As a result, eligible veterinarians may have elected to decline participation in another investigative exercise into their practice; while those who chose to participate may have altered their responses in order to show a higher level of compliance with government recommendations in regards to IC/HeV management. Although it is difficult to gauge the validity of the results, the responses given by participating veterinarians in this study corroborate some of the findings from an exploratory qualitative study conducted by the authors in 2009–2010 (Mendez et al., 2012a,b, 2013b).

5. Conclusion

Despite a marked increase in the number of HeV cases in 2011, there were no new human cases of HeV. This may indicate that QLD veterinarians were protecting themselves and/or managing HeV better than in the preceding years. The unusual epidemiology of HeV during this time may have served as a motivation boost for the veterinary profession and biosecurity authorities to improve HeV management. It also tested the newly developed HeV management strategies put in place by Biosecurity QLD from 2010 onwards: better flow of information and support in the field to veterinarians and horse owners. The results of this study seem to confirm that private veterinarians can better fulfil their biosecurity, public health and WHS roles, when dealing with emerging zoonoses such as HeV, when supported by the relevant authorities. This should be taken into consideration when devising strategies to manage future emerging zoonoses. However, despite the improved HeV management support provided by

government authorities to the veterinary profession in QLD, HeV management strategies and behaviours were not found to be optimal across all participants and their practices, leaving some veterinarians at risk of exposure to HeV. The uptake of improved veterinary IC strategies by the private veterinarians may therefore depend upon other factors, such as risk perception, which should be further investigated. Moreover, until the HeV vaccine coverage of equine populations is consistently high across QLD and Northern NSW; IC, including the use of appropriate PPE, remains the best course of action to prevent human exposure to HeV. Therefore, HeV-related risk information and risk mitigation communication to veterinarians and horse owners need to remain a priority of the overall HeV management plan at the State and National levels. This should include regular updates about HeV to the veterinary profession, particularly advances in knowledge; education of horse owners; practical HeV management education to veterinarians; and the consistent education of undergraduate veterinary students Australia wide. The determinants of veterinary IC should also be further investigated in particular the role of undergraduate and professional education.

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