ESTONIAN UNIVERSITY OF LIFE SCIENCES
Institute of Veterinary Medicine and Animal Sciences

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THE CLINICAL DECISION-MAKING PROCESS AND THE POTENTIAL IMPACT OF THE GEKKOVET CLINICAL DECISION SUPPORT SYSTEM ON DIAGNOSTICS IN VETERINARY MEDICINE

KLIINILISTE OTSUSTE TEGEMISE PROTSESS JA GEKKOVETI KLIINILISTE OTSUSTE TOETUSSÜSTEEMI VÕIMALIK KASUTEGUR DIAGNOSTIKALE VETERINAARMEDITSIINIS

Final Thesis
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Supervisor: Martin Karindi, DVM

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Clinical decision-making is a multidimensional process, and factors common to any kind of human decision-making cause biases. Errors in clinical decision-making are common and significantly impact individuals and society. In veterinary medicine, as in human medicine, an increased amount of clinical data and information has created a need for clinical decision support systems (CDSS).

In this study, was evaluated veterinarians' ability to build differential diagnosis lists in four real-life internal medicine cases. In each case additional information about the patient was provided in three phases. Forty-seven licensed veterinarians completed the survey. In the CASE 4 over 90% found the correct diagnosis. Seventy-seven percent of the respondents answered correctly for CASE 2, while lower scores were in CASE 1 and CASE 3, with 47% and 55% of respondents providing correct diagnoses, respectively. GekkoVet CDSS got all four cases correctly diagnosed in the last phase of the case (respondent average: 2.7). In total, GekkoVet scored 8 out of 12 possible right answers, whereas 6.19 was the average score among respondents. Those respondents who used external help did spend more time (p-value 0.034) to complete the questionnaire. It is notable that using external sources and more time did not significantly improve respondents' result. Experience as a practicing veterinarian did not influence the average number of diagnoses, the amount of time spent to complete the survey or the number of correct diagnoses at a statistically significant level.

Based on this study and literature published previously, CDSSs have the potential to reduce clinicians' workloads and help them make more diagnoses faster and with greater confidence. Along with potentially increased clinical performance, CDSSs might reduce the burden veterinarians experience from clients and employers. Certain cautions and limitations should be considered when implementing CDSSs for clinical use.

Keywords: CDSS, AI, diagnostic tool, diagnostic process

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Kliiniliste otsuste langetamine on mitmemõõtmeline protsess, mis on mõjutatud inimeste eelarvamustest. Vead kliiniliste otsuste tegemisel on sagedased ja mängivad olulist rolli nii üksikisiku kui ka ühiskonna tasandil. Sarnaselt humaanmeditsiinile on veterinaarmeditsiinis suurenenud kliiniliste andmete ja teabe hulk tekitanud vajaduse kliiniliste otsuste tugisüsteemide (CDSS) järele.

Käesolevas uuringus hinnati veterinaaride oskust koostada diferentsiaaldiagnooside nimekirju nelja reaalse haigusjuhtumi puhul. Patsientide kohta esitati lisateavet kolmes etapis. Küsimustikule vastas 47 veterinaararsti. Enim korrektseid vastuseid esitati 4. JUHTUMILE, kus üle 90% vastajatest jõudis õige diagnoosini. Täpset diagnoosi mainiti 2. JUHTUMI puhul 77% kordadest, samal ajal kui 1. ja 3. JUHTUMI puhul vastas õigesti vastavalt 47% ja 55% küsitletutest. GekkoVet CDSS poolt välja pakutud võimalike diagnooside hulgas oli kõigi juhtumite viimaseks etapiks nimetatud korrektset diagnoosi (vastajate keskmine: 2,7). Kokkuvõttes mainis GekkoVet õiget diagnoosi 8 korral 12-st võrreldes vastajate keskmisega 6,19/12. Välist abi kasutanud vastanutel võttis küsimustiku lõpetamine kauem aega, $p = 0{,}034$. Lisamaterjalide kasutamine ja pikem vastamise aeg ei mõjutanud oluliselt vastamistulemusi. Nimetatud diferentsiaaldiagnooside arv, vastamisele kulunud aeg ja korrektsete vastuste kogus ei olnud statistiliselt olulisel tasemel mõjutatud veterinaaride töökogemuse pikkusest.

Käesoleva ja varasemate uuringute põhjal on CDSS-del potentsiaal aidata arstidel jõuda diagnoosini suurema kindlustunde ja lühema ajakaoga. Lisaks erialase võimekuse parandamisele kaasneb CDSS-dega võimalus veterinaararstide töökoormuse vähendamiseks. Kliiniliseks kasutamiseks mõeldud CDSS-ide rakendamisel tuleks arvestada teatud ettevaatusabinõude ja piirangutega.

Märksõnad: CDSS, AI, diagnostikavahend, diagnostikaprotsess

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LIST OF ABBREVIATIONS

ADE — adverse drug effect

AI — artificial intelligence

ASCCP — American Society of Colonoscopy and Cervical Pathology

CDSS — clinical decision support system

CPOE — computerized provider order Entry

CRSS — clinical reasoning support system

HI — hybrid intelligence

ICU — intensive care unit

IM — internal medicine

ML — machine learning

QP — QuestionPro

ME — Microsoft Excel

INTRODUCTION

Medicine’s goal is to cure, care for, and comfort. One possible cause of suffering is not knowing the cause of symptoms. Clinicians can relieve this suffering when providing a diagnosis, not only when there is a suitable treatment, but also when the diagnosis offers closure, even without treatment possibilities (Cassell, 1998). Diagnosis can rightfully be seen as a goal in medicine, and most clinicians make diagnoses or other clinical decisions daily. Nevertheless, the accuracy involved in achieving this goal requires significant attention (Reyers, 2005).

Diagnoses, the diagnostic process, and clinical decision-making are important research areas due to their potential impacts on the development of medical science and patient safety. Particularly important are discovering teaching methods and helping future clinicians improve their critical thinking and accuracy (McKenzie, 2014). Currently, to achieve a correct diagnosis, it is crucial for clinician to memorize the details of thousands of diseases and conditions. A good clinician must also apply that information and make decisions quickly. These demands easily lead to biased results, which may harm patients. Unfortunately, as with critical thinking, teaching these skills is challenging (Young *et al*., 2018). In summary, it can be stated that there are difficult requirements, but the lack of skills can lead to biased results that may harm patients.

This is a descriptive study which evaluated the GekkoVet clinical diagnostic support system (CDSS). The literature review chapter explores the diagnostic process, the way human and veterinary clinicians make decisions and diagnoses, the possible reasons for medical errors, and the consequences of making them. This chapter also discusses the effectiveness, current state, and future possibilities of CDSSs. The aims of the current study are presented in Chapter 2, and Chapter 3 presents study methods in more detail. Chapter 4 comprises the results and analysis of the collected data. Chapter 5 discusses drawing conclusions about the current research by comparing it to previous research.

The aforementioned area of study is significant because wrong or delayed diagnoses can harm patients (Kohn et al., 2000). In the context of veterinary medicine, such diagnoses can have a potentially negative effect on the relationship between the client and the veterinarian There might also be a severe negative impact on the veterinarian’s self-esteem and mental well-being (Mellanby and Herrtage, 2004). Studies such as this can provide information about the future possibilities of CDSSs and how they should be further developed.

1. LITERATURE REVIEW

1.1. Diagnosis

Diagnosis, one of the main goals in medicine (Singh *et al*., 2017), is defined as a clear, short, specific description determining a present disease or condition and its possible causative agent(s), as well as other finding(s) (McKenzie, 2014). Using appropriate, widely accepted professional terminology is necessary when determining a diagnosis. Differentiating confirmed diagnoses, for example, dilated cardiomyopathy, from clinical signs, such as tachycardia or low blood pressure, is also important. Clinical signs alone never constitute a diagnosis (Reyers, 2005). Despite the importance of diagnoses, only a limited number of studies have been undertaken on veterinary diagnostics and the training of veterinary medicine professionals involved in making correct diagnoses.

1.1.1. The diagnostic process and clinical decision-making

The diagnostic process and clinical decision-making are a clinician's most important skills. Understanding these difficult, multidimensional processes is integral to making a correct diagnosis and, above all, ensuring patient safety. The only way to achieve these goals is to thoroughly investigate and identify thinking patterns during diagnostic processes and to understand how clinical decisions are usually made. Clinicians make diagnostic decisions in the same way as anyone else in any other decision-making situation. Like any decision-maker, clinicians are naturally predisposed to biased conclusions (Croskerry, 2009). Several noteworthy theories explain the diagnostic thinking process, and it is difficult to provide comprehensive definitions or guidelines for it (Young *et al*., 2018). McKenzie (2014) also notes that every patient and situation is unique, preventing the creation of an all-inclusive model for the diagnostic process.

For decades, the dual-process theory has been one of the most widely accepted decision-making theories in psychological research. It is based on two systems. System 1 is traditionally described as an intuitive, heuristic approach. System 2 is expressed as a systematic, analytical way of thinking. Diagnostic processes and clinical decision-making can be consciously or unconsciously directed in either direction but are often a combination of the two systems. Clinical decision-making is never just about thinking; it is strongly influenced by real-world constraints (Croskerry, 2009; Kahneman, 2011).

Diagnoses and clinical decisions based on System 1 can be described as “pattern recognition.” This more biased method, compared to System 2, usually results in quick decisions because it is based on previously experienced cases presented under familiar circumstances (Kahneman, 2011). Decisions made this way seem secure and correct. More experienced clinicians, in particular, regularly make the correct decision or diagnosis when they rely on this straightforward method. The weaknesses of System 1 are apparent when a case is atypical and, for example, a classic clinical sign is missing or the situation is otherwise unfamiliar to the clinician. Unfortunately, such situations are likely to lead to incorrect clinical decisions or diagnoses with undesired consequences (Croskerry, 2009).

In contrast to System 1, System 2 holds a significant advantage when a case has atypical clinical signs or some of its most characteristic signs are absent. This more critical approach does not rely on suggestions, intuition, or previously experienced situations. System 2 offers a systematic, logical approach and uses all the relevant available data for clinical decision-making, thus ensuring that the results are as accurate as possible. Nevertheless, this kind of analytical and algorithm-based thinking naturally gives results much more slowly and requires much more active consideration of a potential diagnosis than System 1 (Croskerry, 2009; Kahneman, 2011).

When trying to improve the diagnostic process and clinical decision-making, understanding dual-process theory and critically evaluating one’s decision-making process are essential. Awareness of cognitive biases is especially important in unexpected and rapidly occurring events such as those in intensive care units (ICUs). This need for awareness also applies to students, recent graduates, and experienced clinicians. It is important to note that neither system is flawless. Skilled clinicians can recognize the pitfalls of their thinking and create a suitable combination of Systems 1 and 2 for each situation (Croskerry and Norman, 2008).

1.1.2. Definition and significance of medical errors

Medical errors can be defined as errors or mistakes that harm patients. Such harm can be caused by, for example, misdiagnosis, delayed diagnosis, adverse drug effects (ADEs), surgical errors, the failure to act on the results of monitoring or testing, and the use of outdated tests or therapies. Errors are considered true mistakes. Malpractice, like out-dated standards, is not considered to involve honest errors, even though it might adversely affect patients (Leape, 1993; Gay, 2017).

Medical errors impact patient safety. They have been known to cause more fatalities than traffic accidents, AIDS, or breast cancer in the United States. Notably, ADEs lead to more deaths than workplace injuries. Such a large number of deaths creates a society-wide need to avoid medical errors. Medical errors are clearly a significant issue if one also considers the financial and social damage they cause. Considering the seriousness of medical errors, there should be much more discussion about them (Kohn *et al*., 2000).

Gawande (2002) described the unexpectedly high differences between ante-mortem and post-mortem diagnoses confirmed in autopsies. He showed that there were 20-40% misdiagnoses and that 33% of misdiagnosed people could have been saved with a correct diagnosis. Gay (2017) stated similar results from veterinary medicine necropsies, even though there has been some improvement over the decades. Wallis *et al*. (2019) confirmed that while medical errors in veterinary medicine impact patient safety, they remain understudied.

Mellanby and Herrtage (2004) investigated the mistakes of recent veterinary graduates. They defined mistakes as erroneous acts or omissions resulting in a less-than-optimal or potentially adverse outcome for the patient. They found that 78% of recent graduates had made a mistake and that the biggest risk of making a mistake was during the first 18 months after graduation. They found that 23 of 73 (32%) mistakes were linked to diagnostic procedures. However, they did not determine how mistakes later affected patients or how severe the consequences were. Their most significant finding was the impact on the veterinarian involved. Many recent veterinary graduates noted a loss of self-confidence, excessive stress, guilt, or depression after a mistake. Some respondents were unsure whether they should continue practicing veterinary medicine. These results highlight the need for protocols and systems to avoid diagnostic errors, especially for the safety of patients and the well-being of veterinarians (Mellanby and Herrtage, 2004).

1.1.3. Reasons for and types of errors in veterinary medicine

Medical errors can be classified in many ways, but one common way is by distinguishing between cognitive and system errors (Graber *et al*., 2005). Cognitive errors involve mistakes, forgetfulness, distractions, a lack of knowledge, and biased decisions, for example, the premature closure of a medical case without considering other options. Cognitive errors are associated with an individual’s work, such as that of a veterinarian, and are more frequent in stressful situations. In contrast, system errors are related to an entire unit's, such as a veterinary hospital, operation, or culture. System errors can result from incorrect policies, a lack of teamwork or communication, poor management, or ineffective processes (Graber *et al*., 2005).

Wallis *et al*. (2019) undertook one of the largest studies of medical errors in veterinary medicine. They identified the three most common types of medical errors as drug-related, communication-related, and oversight, which the study defined as diagnostic errors. Oxtoby *et al*. (2015) obtained similar results, although their categorization was slightly different. They also established that the majority of medical errors were cognitive. Surprisingly, their study showed that a lack of communication was related to only 5% of medical errors. Oxtoby *et al*. (2015) also determined that the veterinary medicine–specific "owner effect" contributed to 15% of medical errors. They defined ascribed "owner effect" to losses to follow-up investigations and the refusal of recommended treatment options for either financial or emotional reasons. Mellanby and Herrtage (2004) found that recent veterinary graduates mentioned lack of experience, time, and supervision as reasons for mistakes. These are classified as cognitive errors and follow the same trends as other studies (Graber *et al*., 2005; Singh *et al*., 2017). McKenzie (2014) concluded that veterinarians concerned about the time spent on diagnostics were unwilling to take a systematic approach and were, therefore, more prone to errors.

Mellanby and Herrtage (2004), Oxtoby *et al*. (2015), and Wallis *et al*. (2019) noted the significant bias in these kinds of studies, which were based on previously collected data or surveys in which veterinarians and their staff self-reported medical errors. There is a risk of incorrect reporting or a failure to report medical errors. Thus, the actual number of medical errors is even greater than reported. Oxtoby *et al*. (2015) even stated that the causes of errors are not profession-specific but are mostly universal. This definition justifies that medical research about medical errors may be referred to in the context of veterinary medicine and vice versa.

1.1.4. Ways of reducing medical errors

Medical errors are a sensitive topic. Errors are easily seen as individuals' fault rather than system-level issues. Veterinarians are unwilling to expose their mistakes to third parties. Even studies related to medical errors avoid using the word "error". The fear of potential consequences has also greatly impacted reporting willingness and led to biased results. Typical medical traditions and cultures make it relatively difficult to study and recognize harmful practices and determine ways of improving on a system level (Gay, 2017; Wallis *et al*., 2019). Tivers (2015) suggested that accepting that medical errors happen is the only way to reduce their occurrence. He also noted that creating a formal system for collecting medical error data in veterinary medicine, as is done in human medicine, could help avoid medical errors in the veterinary field.

Both the aviation industry and nuclear power plants have strict procedures with high reliability due to the severe risk they involve (Singh *et al*., 2006; Gay, 2017). Implementing similar standards in medicine, such as guidelines and step-by-step checklists, from such high-reliability organizations has been shown to improve patient safety and remarkably reduce medical errors in surgical procedures. The greatest recorded improvement in patient safety was that the adjustable pressure-limiting valve was never closed during an operation when using a checklist (Hofmeister *et al*., 2014). The valve is crucial to patient safety; it needs to be closed during testing the anesthesia machine but opened before connecting the patient. McKenzie (2014) noted the importance of checklists and algorithm-based diagnoses. He provided clear evidence that when a diagnosis is rule-based and standardized, there is less room for error. Many clinicians believe in their ability to draw correct conclusions and diagnoses without checklists or guidelines. This thinking is based on the uniqueness of every patient and situation. Thus, checklists are considered unsuitable because they do not consider possible variations. Even when considering a variety of cases, it has been shown that diagnostic reliability decreases when clinicians make decisions independently rather than collectively (McKenzie, 2014).

Still, certain standards should be met to ensure potential benefits of checklists. Widely accepted standards and adequate clinical research are essential for compiling and generating checklists and other guidelines for diagnostics. Clinicians must have easy access to relevant, trusted information, and this access must be readily available (McKenzie, 2014). Reducing medical errors involves combining multiple factors. A checklist, a culture that allows mistakes, good communication, and guidance are crucial elements for reducing errors in all areas of veterinary medicine (Hofmeister *et al*., 2014; McKenzie, 2014; Gay, 2017; Wallis *et al*., 2019).

1.2. Clinical decision support systems

Different CDSSs have been used for decades. The continuous development of medicine has led to the creation of different CDSSs. The development of CDSSs has aimed to increase the accuracy of diagnosis, reduce workload, obtain diagnoses faster, and thus reduce healthcare costs. Medical knowledge and data collected from patients have increased enormously in recent decades (Haux, 2006; Teufel and Binder, 2021). There is so much information that people cannot reliably consider it all when making clinical decisions. Decades ago, a handout was sufficient and, therefore, a much-used source of information for medical professionals. Currently, CDSSs, depending on their use, must either manage complex scenarios and evaluate probabilities or contain a large amount of reliable, easily accessible information (Hemmerling, 2009; Bright *et al*., 2012).

Along with requiring complex computer programs using big data, artificial intelligence (AI), and machine learning (ML), CDSSs use much simpler tools. These simple tools include multiple helping solutions, such as automated alerts, guidelines, checklists, summaries, drug dose calculators, consultations, and telemedicine tools (Hemmerling, 2009; Teufel and Binder, 2021). There are multiple strategies for building CDSSs, and their contribution to diagnostics can be either active or passive. Active CDSSs can work autonomously in the background and automatically give alerts or suggestions to the clinician. Passive systems usually involve more effort by clinicians, as they require the manual input of patient data and, at least, a partially manual interpretation of results. CDSSs use an entered or existing database and might use AI and ML separately or together. CDSSs can be built into electronic health records, where they are easily accessible. CDSSs can work as individual programs, which is more typical of passive CDSSs (Schuh *et al*., 2018; Sutton *et al*., 2020).

One major subtype of CDSS is computerized provider order entry (CPOE), an electronic system for ordering medications, laboratory tests, and imaging. CPOE can be either part of a CDSS or an individual program. Like CDSSs, CPOE can work actively or passively and warn clinicians of, for instance, ADEs and drug–drug interactions, which can also be considered ADEs. CPOE reduces systematic, random, and communication errors (Prgomet *et al*., 2017; Sutton *et al*., 2020).

An increasing number of studies on CDSSs have garnered interest among researchers. Searching "CDSS" on the National Library of Medicine online database produced 2,543 results, 1,858 (73%) of which were published in 2013 or later. Remarkably, 726 of the studies (29%) were published in 2020 or later (NML, 2022). This data indicates that researchers have only recently paid significant attention to CDSSs.

1.2.1. Application of CDSSs in human medicine

Modern CDSSs have been used in many areas of human medicine. A variety of therapy areas makes it difficult to produce a CDSS for widespread use. Nevertheless, studies of different kinds of CDSSs have been encouraging. These clinical situations include automated anesthesia, ADEs, ICU mortality, cancer detection, allergy monitoring, triage classification, rare disease diagnosis, pathology, imaging, and laboratory results interpretation (Hemmerling, 2009; Bright *et al*., 2012; Prgomet *et al*., 2017; Ravikumar *et al*. 2018; Schuh *et al*., 2018; DiPietro Mager, 2019; Dramburg *et al*., 2020; Fernandes *et al*., 2020; Pallua *et al*., 2020; Schaaf *et al*., 2021).

Even though comparing CDSSs and evaluating their clinical performance is difficult, multiple studies have been undertaken in recent years that have indicated their potential positive impact (Vasey *et al*., 2021). Van Cauwenberge *et al*. (2022) concluded that most clinicians were willing to use CDSSs to manage routine tasks. Most clinicians believed that CDSSs allowed them to work more quickly and accurately. The clinicians also noted that they could learn while using CDSSs.

The most effective, statistically significant results were achieved when there were CPOEs (Prgomet *et al*., 2017; Sutton *et al*., 2020). During 12–24-month study periods, ADEs decreased by 85% and the mortality rate decreased by 12% compared to situations when CPOEs were not used in ICUs (Prgomet *et al*., 2017). Sutton *et al*. (2020) found that CPOE resulted in cost reductions without adverse effects.

Ravikumar *et al*. (2018) studied CDSS for cervical cancer screening and surveillance. Their study used a CDSS prototype that they modified to follow the latest American Society of Colposcopy and Cervical Pathology (ASCCP) guidelines. They compared the recommendations received from CDSSs to those of cancer specialists. The accuracy of the CDSS was 96.7% in routine cases and 83.7% in atypical cases, compared to the specialists' recommendations. Despite limitations, like the manual work related to the use of a CDSS, Ravikumar *et al*.'s (2018) study showed that following algorithmic guidelines for a CDSS can obtain good results. Doing so is especially helpful if no specialists are available. However, it was noted that the CDSS correctly made recommendations that specialists missed in four cases when researchers thoroughly checked cases after evaluations by CDSSs and experts.

Kunhimangalam *et al*. (2014) used a CDSS to determine neurological conditions as early and effectively as possible. They entered the clinical symptoms and the information from a nerve conduction study. In total, they entered 104 cases into a CDSS that used fuzzy logic mimicking human thinking. In fuzzy logic, results are not just "yes" or "no," but have a truth value between 0 and 1. Compared to experts' opinions, CDSSs showed 93% accuracy. As early treatment for neurological conditions is essential, they concluded that CDSSs should not replace specialists but that general practitioners could use them.

Vasey *et al*. (2021) screened 5,154 abstracts and eventually fully evaluated 156 studies. A total of 107 of the 154 studies showed statistical significance. Of the 107 statistically significant studies, 54 (50%) showed that CDSSs improved measured values. A total of 49 studies (46%) did not indicate improvement or obtained unclear results. Their study indicated that obtaining proof of CDSSs' effectiveness and building a properly measurable test environment are difficult. They also underlined the lack of consideration of human factors and user feedback in the reviewed studies. As previously noted, clinical decision-making is complex, and measuring it is even more so. One finding was that the greatest improvement in measured metrics was seen among less experienced clinicians.

1.2.2. Concerns about and attitudes toward CDSSs

Implementing CDSSs in a clinical setting involves various potential risks (Schuh *et al*., 2018). Again, people are prone to errors resulting from absent-mindedness, whereas incorrect data in CDSSs results in systematic errors or biased information. The most obvious risk relates to data imported to the CDSS. It must be accurate and regularly updated to reflect recent medical developments. The data in CDSSs could be inaccurate due to developers' lack of knowledge. CDSSs with ML or AI might be too autonomous and draw incorrect conclusions in the variable context of medicine. Therefore, medical professionals should focus on developing CDSSs. Severe risk also occurs when there is a conflict of interest between a developer and an end user.

From the users and patients' viewpoint, there is a risk that CDSSs might provide favorable suggestions that, nevertheless, can cause harm to end-users (Sikma *et al*., 2020; Vasey *et al*., 2021).

One common user-related issue is alert fatigue. Automated CDSSs actively provide suggestions and alerts regarding clinical decisions. Studies have shown that clinicians ignore relevant alerts when most alerts are inappropriate or there are simply too many of them. Frequent alerts also interrupt clinicians' workflow and thus negatively impact productivity. Another user-related issue is that CDSSs and CPOE potentially risk making clinicians too passive or reducing their ability to work without the support of CDSSs or CPOE (Prgomet *et al*., 2017; DiPietro Mager, 2019).

Van Cauwenberge *et al*. (2022) studied clinicians' concerns about implementing CDSSs. The clinicians indicated a concern that the data would result in irrelevant recommendations. They also did not want CDSSs to disrupt their workflow and stated that CDSSs should be incorporated into their work routines. Clinicians also felt that their standing as experts was threatened, and they were worried about their status, especially if CDSSs involved AI. They also noted that medicine is too complicated to be automated but did not rationalize this belief. Sikma *et al*. (2020) and Van Cauwenberge *et al*. (2022) confirmed clinicians' concerns about losing the human element of decision-making. Another risk they recognize is that, from the patient's point of view, giving full control to CDSSs involves both ethical and medical risks. Still, Van Cauwenberge *et al*. (2022) found that clinicians believe they would logically justify overruling CDSSs to avoid incorrect diagnoses due to clinicians' biased evaluation of a situation.

1.2.3. Future possibilities for CDSSs

Vasey *et al*. (2021) suggested evaluating CDSSs along with clinicians' performances rather than only evaluating CDSSs' performances. They see the potential for CDSSs, especially in supporting clinicians with less experience. Ravikumar *et al*. (2018) and Kunhimangalam *et al*. (2014) also observed that CDSSs could offer close-to-expert-level knowledge that would be especially useful for less experienced clinicians. CDSSs could also be useful in situations in which no expert is available, for instance, in developing countries or rural areas. Vasey *et al*.'s

(2021) and Sutton *et al*.'s (2020) recent comprehensive studies found that further research could significantly improve CDSS diagnoses.

Similar views were expressed in a study by van Baalen *et al*. (2021), which proposed a future direction for CDSS development. They suggested combining clinician intelligence with AI to create hybrid intelligence. They referred to this kind of CDSS as clinical reasoning support systems (CRSSs). By definition, "CRSS" better describes working together with a clinician. "CDSS" refers more to help in the form of ready-made solutions than to a reasoning aid. Their study suggested that CRSSs could aid clinicians in finding the most reliable information or procedure. They identified clinicians' most important tasks as defining the needed information, collecting it from the patient, and inserting it into CRSSs. They did not suggest blindly trusting CRSSs but encouraged clinicians to carefully interpret the results and, after careful consideration, take action accordingly.

1.2.4. GekkoVet CDSS

The literature has not much studied CDSSs for veterinary medicine, but research on CDSSs in human medicine may indicate possibilities for veterinary use as well. GekkoVet is a diagnostic tool for veterinarians that can be used with a mobile or desktop app. Currently, GekkoVet can be used to assist with feline and canine internal medicine. GekkoVet uses real-world data from veterinary medicine. Veterinarians can use it for clinical reasoning in three ways: by entering symptoms, by searching for diseases, or as a CPOE. A user adds symptoms and basic information about a patient. GekkoVet then lists all the potential diagnoses matching those symptoms in order of probability. It is also possible to mark the most relevant symptoms as required or filter the result by relevant geographical areas. GekkoVet provides typical symptoms, signalments, causes, general information, information on how to confirm or exclude the disease, and treatment information. The user can also search for diseases by species, name, breed, or different causes. GekkoVet then provides information about the disease (GekkoVet, 2022).

2. STUDY AIMS

This study aimed to evaluate veterinarians' ability to build differential diagnosis lists in real-life internal medicine cases. Another aim was evaluating the possibilities of the GekkoVet CDSS. Both were evaluated by counting the total number of differential diagnoses and assessing how correct the suggested diagnoses were. Study also sought to investigate how the use of external sources would affect the correctness of the diagnosis and the time spent. These comparisons were made in groups with different amounts of experience in practice. Another comparison group was veterinarians with national or international specializations in small animal medicine.

3. MATERIALS AND METHODS

Licensed veterinarians answered an online survey covering different internal medicine cases. The veterinarians who completed the survey were located in Finland, Estonia, Australia, Denmark, and the United Kingdom. Real-life internal medicine cases that were used in the questionnaire were provided courtesy of Dr. Med. Vet. Johanna Rieder from the University of Hannover.

3.1. Questionnaires

Data was collected using the online survey tool QuestionPro (QP), provided by the Estonian University of Life Sciences. The published questionnaire can be found in Appendix 1. The questionnaire was published in a Facebook group called *Flutteri*, which is actively used by licensed Finnish veterinarians, and in a similar Estonian Facebook group called *Vetist Sõbrad*. The questionnaire contained four real-life patient cases, two background questions, and two questions about filling out the survey at the end. In each of the four cases, there were three phases. A differential diagnosis list of a maximum of five diseases was asked to be filled out in each phase. In total, 12 differential diagnosis lists, each containing a maximum of five diseases and a minimum of one, were required. The questionnaire was available in English, and free-text answers were allowed to be given either in Finnish or English.

The survey was open to receive answers from March 19, 2023, to April 9, 2023. Veterinarians answered the questionnaire anonymously. There was no guided restriction on the use of external information sources. At the beginning of the questionnaire, a short explanation about the subject and purpose of the study was provided, as were instructions to fill out the questionnaire. In the end, there was a possibility of winning small prizes.

3.2. Questionnaire data

Questionnaire data from QP was exported to Microsoft Excel (ME). The questionnaire was considered complete if at least one accepted differential diagnosis was given in each phase of each case presented. Only these completed questionnaires were counted and exported to ME. Same cases with the same phases were also inputted to GekkoVet CDSS.

To be able to make calculations, data were aligned, as there were some misspellings (e.g., "*Adisson*"), diseases written both in Finnish and in English (e.g., "*hepatiitti*" – "hepatitis"), and different kinds of abbreviations used. There were inaccurate expressions referring to multiple organs (e.g., "gastrointestinal disease") or diseases that are not considered as internal medicine (IM) (e.g., musculoskeletal problems). These were changed to "Not Specific" or "Not IM" and were not counted as a accepted differential diagnosis. Provided diagnoses or conditions that referred to specific organs (e.g., "kidney disease") were accepted. These wider diagnoses were combined with more specific ones (e.g., "kidney disease," "acute /chronic kidney disease," and "pyelonephritis" were all changed to "renal disease"). If the respondent gave two or more diagnoses in the same field, these were changed to different fields if free fields were available. In this case, if the method led to exceeding the maximum number of five filled diagnoses, then the field of multiple diagnoses was changed to "Not specific" and not counted in.

3.3. Cases and the right answers

Confirmed real-life diagnoses were used as reference cases. CASE 1 was Schmidt syndrome, which is known as a combination of Addison's disease with hypothyroidism and/or diabetes mellitus. In CASE 1, responses of "Schmidt syndrome," or that mentioned Addison's with hypothyroidism and/or diabetes mellitus, were calculated as a correct answer. CASE 2 was Addison's disease. CASE 3 was also Addison's disease with distractive characteristics of chronic kidney disease. CASE 4 was a chronic kidney disease.

3.4. Data analysis

Descriptive statistics were used to get an overview of the dataset and to support other analyses. Correlation coefficients and p-values were calculated to explore relationships with different background variables and time spent. Analyses were conducted with IBM SPSS statistics and ME. The Pearson correlation coefficient was calculated with different variables: diseases that respondents had never seen in practice, use of external sources of information, time to complete the survey, and experience as a practicing veterinarian. Spearman's Rho was measured to calculate the association between use of external help and time to complete.

4. RESULTS

4.1. Respondents

The questionnaire was opened 259 times. 158 respondents started to fill out the questionnaire, and of those, 47 (29.8%) completed it. The average time spent was 14 minutes for all respondents and 33 minutes for those who completed the survey.

As presented in Table 1, 47 respondents who completed the survey were relatively experienced; 34% had over 10 years of work experience as a practicing veterinarian; the second largest subgroup was respondents who had work experience of 1-3 years (32%), while 15% had worked 3-5 years, 13% had worked 5-10 years, and 6% had less than a year of experience as a practicing veterinarian. In total, almost half had worked for over five years. Only one respondent had an internal medicine specialisation, and 91% the respondents had no specialist degree in veterinary medicine. Twenty-one percent of the respondents said that they used some external sources of information when answering the questionnaire, although none named GekkoVet CDSS. Twenty-three percent of the respondents wrote about one or more differential diagnoses that they had never seen in practice.

Table 1. Average number of total proposed diagnoses and average time to complete the survey according to experience

Experience as a practicing veterinarian	n (%)	AVG Dx	AVG t (s)
Less than a year	3 (6)	9.00	1981
1–3 years	15 (32)	8.93	2142
3–5 years	7 (15)	9.21	1356
5–10 years	6 (13)	9.08	1969
Over 10 years	16 (34)	8.59	2172

AVG Dx – Average number of entered differential diagnoses per case out of maximum of 12
AVG t (s) – Average time spent in seconds to complete the survey

4.2. Presented differential diagnoses

The averages of the mentioned differential diagnoses are calculated in Figure 1. In CASE 1, a total of 450 differential diagnoses were given; in CASE 2, a total of 438 differential diagnoses;

in CASE 3, a total of 389 differential diagnoses; and in CASE 4, a total of 388 differential diagnoses. In all cases, the number of proposed differential diagnoses decreased as the information about the patient increased in the phases of the survey. The same decrease in the number of differential diagnoses occurred even though, for example, in CASE 1, less than half identified the diagnosis correctly, as presented in Table 2. In the third step of CASE 1, on average, there were more than two blanks. All cases were presented in the same order to each respondent; therefore, describing correlation between the decrease in the total number of differential diagnoses as the survey progresses cannot be calculated.

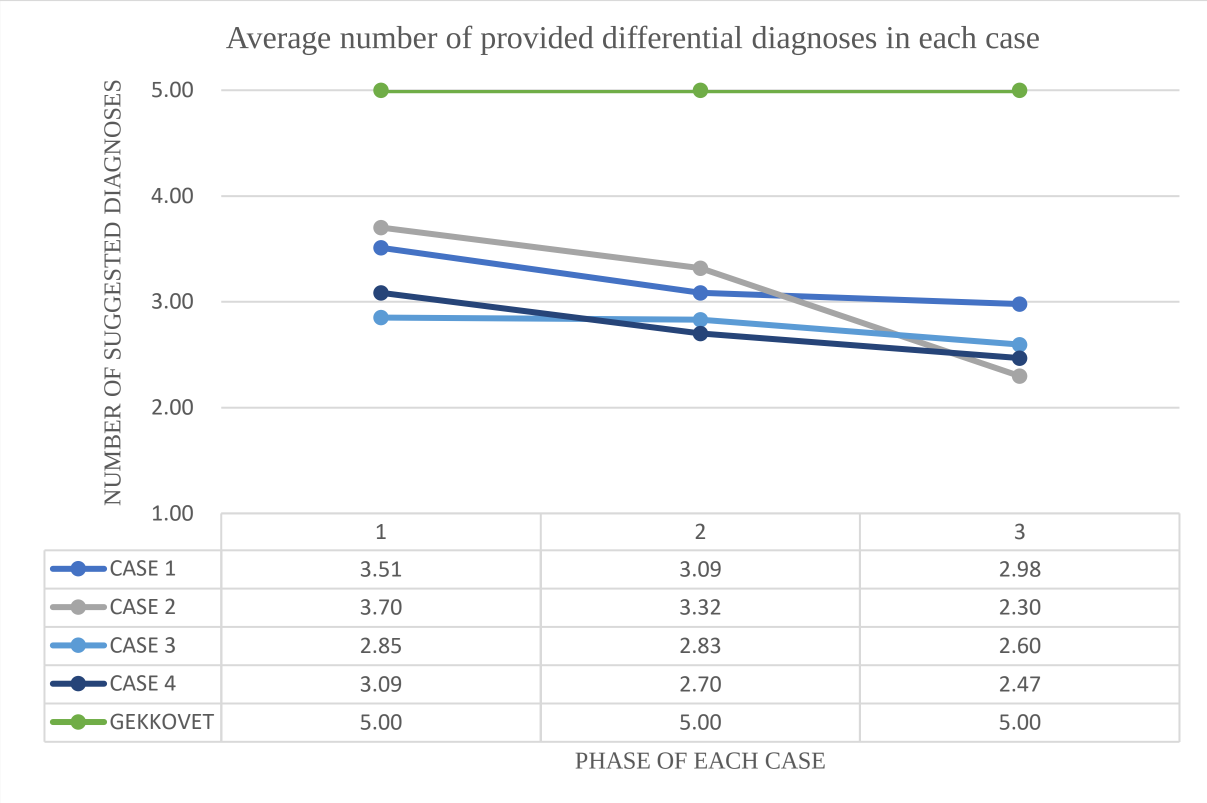

Figure 1. Average number of diseases mentioned in each phase of each case of those 47 respondents who completed the questionnaire and GekkoVet CDSS.

4.3. Number of correct diagnoses

Table 2 presents the total number of right answers of all 47 respondents. CASE 4 was easiest for the respondents: over 90% found the correct diagnosis. 77% of the respondents answered correctly for CASE 2, while the harder ones were CASE 1 and CASE 3, with 47% and 55% of respondents providing correct diagnoses, respectively. There was no decrease in answer accuracy throughout the cases.

Table 2. Number and percentage of right answers out of forty-seven in the phases of each case

Right answers	Phase 1 n (%)	Phase 2 n (%)	Phase 3 n (%)
CASE 1	12 (26)	18 (38)	22 (47)
CASE 2	4 (9)	13 (28)	36 (77)
CASE 3	13 (28)	25 (53)	26 (55)
CASE 4	41 (87)	38 (81)	43 (91)

The number of right answers per respondent is presented in Table 3. Only one respondent did not get any of the cases right; 26% of the respondents provided the correct diagnosis to all cases; 36% provided it to three cases; 23% included two correct diagnoses and 13% of the respondents got one correct diagnosis in the last phase. The average time spent on the survey varied between groups, from a group of 0 right answers (1015 seconds) to a group of 2 right answers (2526 seconds).

Table 3. Number of right answers per respondent in each phase

	Phase 1 n 47 (%)	Phase 2 n 47 (%)	Phase 3 n 47 (%)	AVG t (s)
0 right answers	1 (2)	3 (6)	1 (2)	1015
1 right answers	27 (57)	19 (40)	6 (13)	1810
2 right answers	15 (32)	7 (15)	11 (23)	2526
3 right answers	3 (6)	11 (23)	17 (36)	1934
4 right answers	1 (2)	7 (15)	12 (26)	1800

AVG t (s) – Average time spent in seconds to complete the survey

4.4. Performance of GekkoVet CDSS

The first five differential diagnoses given by GekkoVet CDSS were counted. GekkoVet provided the correct diagnoses to all four cases in the last phase, when all the data were available, as seen in Table 4. On average, respondents got 2.7 right answers out of possible four in the phase three and only 12 respondents provided as many correct diagnoses as GekkoVet. In total, GekkoVet got 8 out of 12 possible right answers, whereas 6.19 was the average of right answers in all the phases per respondent.

Table 4. Answers of GekkoVet CDSS

Right answers	Phase 1	Phase 2	Phase 3
CASE 1	1	1	1
CASE 2	0	1	1
CASE 3	0	1	1
CASE 4	0	0	1

1 indicates that the right answer was included and 0 indicates that it was not included on the list of five differential diagnoses given by GekkoVet.

4.5. Correlations

There was no significant correlation between the right answers in different phases of the cases or in total (p-value > 0.05). The average time spent on the survey varied between groups, but no significant correlation to the number of right answers was found (p-value > 0.05). Experience as a practicing veterinarian did not influence the average number of diagnoses, the amount of time spent to complete the survey or the number of correct diagnoses at a statistically significant level (p-value > 0.05).

Association between use of external help and time to complete was also calculated. A significant correlation was found at the 0.05 level. Those respondents who used external help did spend more time (p-value 0.034) to complete the questionnaire. It is notable that using external sources and more time did not significantly improve respondents' result (p-value > 0.05).

5. DISCUSSION

It must be stated that completing the survey to the end required a considerable investment of time. In this light, the completion rate was relatively high because completion took over 30 minutes on average. The long filling time well echoes the laboriousness of real-world diagnostics. If the respondent thought to fill out the questionnaire quickly during a coffee break, it was not possible, just like it is not with a real internal medicine patient. A relatively high completion rate in such a laborious survey indicates a remarkable interest in diagnostics and a willingness to participate in studies aiming to improve it.

Data unification was mandatory to be able to perform the intended calculations. When the data were processed as described above, the number of correct answers probably increased. This choice was made deliberately because, in real life, it is one of the most important aspects to identify the organ where the defect or disease is located. A stricter handling method could have been applied, but demanding more definite diagnoses would have needed a more controlled test environment and more detailed instructions. In addition, it would have required very highly motivated respondents and could have reduced the completion rate. The strict level of requirements would also have lowered the number of possible conclusions due to the mathematically small sample size.

As aimed, respondents represented widely different experience groups, and the remarkable finding was that no statistical significance was found between groups. Regardless of experience, everyone was able to give almost the same number of differential diagnoses and similar number of correct diagnoses. At all experience levels, using aids or offering a never-before-seen diagnosis was equally typical. In light of these results, no group was found to be better or faster than the other group by a statistically significant difference. Kunhimangalam et al. (2014) proposed CDSSs, especially for less experienced practitioners, but these results suggest the potential benefit regardless of experience. It seemed that response fatigue did not influence the respondents, as there was no decrease in answer accuracy. The share of internal medicine specialists was small, and no true comparison was possible between specialists and general practitioners. As there were no statistical differences between less experienced veterinarians and more experienced ones, the study does not support Mellanby and Herrtage's (2004) observation that practitioners with less experience make more mistakes.

One aim was to study how veterinarians build up cases. Supposedly, for all respondents, the most familiar diseases (CASE 2 and CASE 4) were the easiest ones. Correspondingly, the more unfamiliar CASE 1 and the slightly misleading CASE 3 were the most difficult ones. This result fits well with previous research. Kahneman (2011) and Croskerry (2009) have both shown the difficulty of diagnosis and decision-making in unfamiliar conditions. In each patient case of the study, there are plenty of potential differential diagnoses at the beginning when the clinical findings do not limit the possible diagnoses. In the last phase, the clinician should be either very confident of being correct or still trying to provide the maximum number of possible differential diagnoses. In this study, this was not the situation, such as in CASE 1. There were still over two blanks on average, but less than half of respondents reached the correct diagnosis. This supports the findings of Graber *et al*. (2005) about cognitive errors, especially biased decisions like the premature closure of a medical case without considering other options.

In every case, the last phase had more correct answers than the previous phases. This also applied to GekkoVet CDSS, which suggested correct diagnosis in all cases at least in the last phase. The number of differential diagnoses offered by respondents decreased phase by phase. This may indicate an improvement in diagnostic accuracy when more data are available. The result is encouraging because it shows it is possible to end up with a correct diagnosis eventually. Unfortunately, in real-life, increasing patient data means multiple expensive examinations. Costs to the owner can have a negative impact on the veterinarian-client relationship (Mellanby and Herrtage, 2004).

The only statistically significant finding was discouraging. It took more time to fill in the questionnaire when using external sources, but this did not improve the result. This possibly refers, that reliable and easily accessible sources, which could actually help, are not widely used in veterinary medicine. The average number of right answers was 2.7 out of four in phase three and, in total, 6.19 out of 12. Results suggest that with GekkoVet CDSS, the survey respondents may have outperformed these averages.

Despite the encouraging results, it is necessary to remember the difficulty of creating a test environment and the challenging nature of demonstrating the effectiveness of CDSS scientifically; these concerns are also mentioned by Vasey *et al*. (2021).

For example, further conclusions could be made with a larger sample size and a large comparison group of veterinarians who would have used GekkoVet to answer the survey. Despite the difficulty of the research field, the research answered the study's aims as well as possible with this number of respondents.

CONCLUSIONS

Errors in diagnosis and clinical decision-making are common but cause serious problems. Making quick, correct diagnoses as cost-effectively as possible is the clinician's main goal. Clinicians should perform at a high level in all possible circumstances, for instance, when in the ICU or when controlling patients' medications, even those they did not prescribe. Clinicians should have access to all possible tools to achieve these goals. The previously mentioned studies showed that modern CDSSs are most effective when used in situations in which certain strict protocols or guidelines are followed. In real-life, such rules are difficult to remember, not only for inexperienced clinicians, but also for expert clinicians. For one example, there are hundreds of drugs and maybe even more drug-to-drug interactions. Possible ADEs are difficult to remember, but once programmed correctly into a CDSS, they will remain relevant if regularly updated.

As the knowledge and data collected from patients have increased enormously in recent decades. In addition, possible tests and imaging possibilities have increased significantly over the years. However, the potential is enormous if we can get the same results with faster and lower examination costs in the future, regardless of the practitioner's experience level. This could revolutionize diagnostics, especially in remote areas or developing countries where a specialist may not be available. The results of this thesis support the hypothesis that CDSSs could improve diagnostics regardless of the level of experience.

Nowadays, a modern CDSS could be seen as a kind of checklist. It makes sure that no possible diagnosis that fits the symptoms gets ignored. As shown in this study, a CDSS provides a greater number of suitable differential diagnoses for clinicians, and a broader sight could lead to better results. This was possibly the situation with the misleading case in which results were consistent with chronic kidney disease but turned out to be Addison's disease. As previous research has also suggested, a CDSS is at its best in atypical and misleading situations. Successful use of a CDSS requires familiarization with and understanding of the operation. How does the CDSS sort the results, and how should the clinician interpret the differential diagnosis list?

Considering the need and current research interest, it is likely that even more effort is being put into the development of CDSSs. The evolution of CDSSs has been continuous, as they have advanced from relatively simple drug calculators to more advanced CPOEs and then to CDSSs that might perform close to an expert level. The next step will likely be to increase their accuracy even further. Big data, ML, and AI might help develop CDSSs even further. When taking these steps, ethical considerations should be given significant attention, and it should be ensured that CDSS suggestions are based on the most recent scientific research and do not give biased results—either accidentally and intentionally.

There is a possibility that CDSS development may scare some veterinarians, especially more experienced veterinarians. Attitudes requires more research in the future. CDSSs will probably only change the veterinarian’s role from an information bank to a more practical one. For example, misleading case might have been solved with CDSS or CRSS if the practitioner had taken a moment and looked at the differential diagnosis list provided by GekkoVet. In addition, the advantage of these programs is that they not only remind people about possible diagnoses, but they also provide all the additional information about the disease or condition and, if necessary, information about the treatment too.

In a broader sense, communication skills and an excellent knowledge of physiology will play a more significant role than just remembering diseases. In the future, a definite diagnosis can be easily sought, for example, from CDSS or CRSS in the future. Even at the time of writing this thesis, the use of AI has taken huge leaps forward.

ACKNOWLEDGMENTS

I encourage everyone to find their own path and follow it. I thank everyone who helped me along my own path. Remember to enjoy the journey and keep in mind these wise words:

“Dreams without goals are just dreams, and ultimately, they fuel disappointment. On the road to achieving your dreams, you must apply discipline, but more importantly, consistency, because without commitment, you will never start, but without consistency, you will never finish.”

— Denzel Washington

“Hard times create strong men, strong men create good times, good times create weak men, and weak men create hard times.”

— G. Michael Hopf

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APPENDICES

Appendix 1. The questionnaire in screenshots

Survey on veterinary internal medicine diagnostics

The diagnostic process and clinical decision-making are the most important skills of a clinician. Understanding these difficult, multidimensional processes is integral to making a correct diagnosis and, above all, ensuring patient safety

This study investigates how differential diagnoses change when the diagnostic process proceeds and how possible diagnoses are related to the information available?

In this survey you are asked to fill out differential diagnoses in different kind of internal medicine cases. It will take approximately 10 minutes to complete the questionnaire. In total there are four different patient cases and in each case there are three steps. Please read the instructions after the background question page carefully.

Your survey responses will be strictly confidential. Your information is anonymous, remains confidential and is only used by the researcher. If you have questions at any time about the survey or the procedures, you may contact Olli Heino at olli.heino@student.emu.ee.

By answering this survey you will help researchers get valuable information about diagnostic process in veterinary medicine. Thank you very much for your time and support. Please start the survey now by clicking on the Start button below.

Start

Survey on veterinary internal medicine diagnostics

Questions marked with a * are required

* How long is your work experience as a practising veterinarian?

- Less than a year
- 1-3 years
- 3-5 years
- 5-10 years
- Over 10 years

Appendix 1 continued

* Do you have a national or international specialist degree on small animal internal medicine? (Official program, residency, diplomate etc. at least equivalent to 120 ECTS. Please not that one year rotation / internship is not considered as a specialization)

- Yes
- No
- Other specialist degree than internal medicine

Next

Survey on veterinary internal medicine diagnostics

In this survey you are presented four different real-life patient cases in total. There are three steps in each patient case. Patient cases are not related to each other. In every step of the case you will get more information about the patient.

First there is only signalment and pre-history, then in the second step you will also get information about the physical examination and anamnesis, and in the third step you will see all the information e.g. laboratory findings about the case. Data available varies in each case.

After every step a differential diagnose list is asked. You need to fill in your differential diagnoses list three times per each case. In each step you can write a new differential diagnose list with maximum of five diseases / conditions. You can write them in any order, all differentials are considered equally important. You can write those in English or in Finnish. There will be some questions about the process after all cases and possibility to take part on draw with a possibility to win amazing prices!

You can suggest the same diseases or change them in every differential diagnoses list. You are not able to return to the previous step / case but all the previous information is available after each step.

☐ I understand that I need to fill in the differential diagnoses lists, three times in each case

Survey on veterinary internal medicine diagnostics

Questions marked with a * are required

* CASE 1: Signalment and anamnesis:

Dog, 1,5 years old, Eurasian, female, neutered

- loss of fur for about a year - with partial improvement after diet change
- lethargy
- recently observed mild gastrointestinal symptoms, faeces with mucus
- normal growth
- exercise intolerance
- reduced food intake

Give maximum of five differential diagnoses, one in each box

Appendix 1 continued

Survey on veterinary internal medicine diagnostics

Questions marked with a * are required

* CASE 1: Interview and physical examination:

No other findings in physical examination but the patient seems extremely depressed

Laboratory results from the referring veterinarian with azotemia, lymphocytosis, reduced total T4 values, elevated TSH values

PREVIOUS INFORMATION:
Dog, 1,5 years old, Eurasian, female-neutered

- loss of fur for about a year - with partial improvement after diet change
- lethargy
- recently mild gastrointestinal symptoms, faeces with mucus
- normal growth
- exercise intolerance
- reduced food intake

Give maximum of five differential diagnoses, one in each box

Appendix 1 continued

Survey on veterinary internal medicine diagnostics

Questions marked with a * are required

* CASE 1: Laboratory findings and other examination results:

Abdominal ultrasound: adrenal glands 0,3 cm, otherwise unremarkable

Ultrasound thyroidal gland: both glands with reduced echogenicity, small, heterogenous retropharyngeal lymph nodes mildly enlarged

Parasitological examination (feces): negative

Laboratory results					Alternative
	Reference values		Results	Unit	Unit
leukocytes	5,05	16,76	13,39	K/µl	E9/l
erythrocytes	5,65	8,87	5,5	M/µl	E12/l
hemoglobin	13,1	20,5	12,2	g/dl	
hematocrit	37,3	61,7	37,6	%	
MCV	61,6	73,5	67,8	fl	
MCH	21,2	25,9	22,1	pg	
MCHC	32	37,9	32,6	g/dl	
thrombocytes	148	484	228	K/µl	E9/l
MPV	8,7	13,2	12,1	fl	
neutrophils	2,95	11,64	5,31	K/µl	E9/l
lymphocytes	1,05	5,1	4,26	K/µl	E9/l
monocytes	0,16	1,12	0,29	K/µl	E9/l
eosinophils	0,06	1,23	3,49	K/µl	E9/l
basophils	0	0,1	0,01	K/µl	E9/l
ALT	10	125	21	U/l	
GlDH	0	10	1,9	U/l	
ALKP	23	212	17	U/l	
bilirubin	0	15	1,88	umol/l	
urea	2,5	9,6	26,4	mmol/l	
creatinine	44	159	208,6	umol/l	
cholesterine	2,84	8,27	5,46	mmol/l	
glucose	4,11	7,94	4,33	mmol/l	
Total protein	52	82	60,9	g/l	
albumine	23	40	32	g/l	
sodium Na+	144	160	142	mmol/l	
potassium K+	3,5	5,8	5,05	mmol/l	
calcium	1,98	3	1,23	mmol/l	
chloride	109	122	120	mmol/l	
pH	7,3	7,45	7,391		
Urinalysis					
Specific gravity	1,016	1,06	1,038		
pH	5	7,5	5,5		
protein			30	mg/ dl	
sediment analysis			epithel cells		
UPC			0,05		
ACTH-stimulation test					
0h	cortisol		< 5,5	nmol/l	
1h	cortisol		< 5,5	nmol/l	
Thyroid hormones					
TT4	13	51,5	0,64	nmol/l	
TSH	< 0,5		5,6	ng/ml	
fT4	7,7	47,6	450	pmol/l	
Thyreoglobulin antibodies				>100%	

PREVIOUS INFORMATION:

No other findings in physical examination but patient seems extremely depressed

Laboratory results from the referring veterinarian with azotemia, lymphocytosis, reduced total T4 values, elevated TSH values

Dog, 1,5 years old, Eurasian, female-neutered

- loss of fur for about a year - with partial improvement after diet change
- lethargy
- recently mild gastrointestinal symptoms, faeces with mucus
- normal growth
- exercise intolerance
- reduced food intake

Give maximum of five differential diagnoses, one in each box

Appendix 1 continued

Survey on veterinary internal medicine diagnostics

Questions marked with a * are required

* CASE 2: Signalment and anamnesis:

Dog, 6 years old, crossbreed, male

- inappetence for 2 days
- vomiting
- diarrhea if fed with dried food

Give maximum of five differential diagnoses, one in each box

Survey on veterinary internal medicine diagnostics

Questions marked with a * are required

* CASE 2: Interview and physical examination:

habitus: depressed
heart rate: 88/min
capillary refill time 3 sec.
able to walk with assistance

PREVIOUS INFORMATION:
Dog, 6 years old, crossbreed, male

- inappetence for 2 days
- vomiting
- diarrhoea if fed with dried food

Give maximum of five differential diagnoses, one in each box

Appendix 1 continued

Survey on veterinary internal medicine diagnostics

Questions marked with a * are required

* CASE 2: Laboratory findings and other examination results:

Abdominal ultrasound:
adrenal glands left 0,3 cm right 0,38 cm
multiple intraprostatic cysts (<0,2cm)
spleen slightly inhomogenous
otherwise unremarkable

Parasitological examination (feces): negative

Laboratory results	Reference values		Results	Unit	Alternative Unit
leukocytes	5,05	16,76	9,19	K/µl	E9/l
erythrocytes	5,65	8,87	12,3	M/µl	E12/l
hemoglobin	13,1	20,5	27	g/dl	
hematocrit	37,3	61,7	81,4	%	
MCV	61,6	73,5	66,2	fl	
MCH	21,2	25,9	22	pg	
MCHC	32	37,9	33,2	g/dl	
thrombocytes	148	484	46	K/µl	E9/l
MPV	8,7	13,2	16,6	fl	
neutrophils	2,95	11,64		K/µl	E9/l
lymphocytes	1,05	5,1		K/µl	E9/l
monocytes	0,16	1,12		K/µl	E9/l
eosinophils	0,06	1,23		K/µl	E9/l
basophils	0	0,1		K/µl	E9/l
ALT	10	125	42	U/l	
GIDH	0	10	2,4	U/l	
ALKP	23	212	12	U/l	
bilirubin	0	15	3,42	umol/l	
urea	2,5	9,6	51,77	mmol/l	
creatinine	44	159	198	umol/l	
cholesterine	2,84	8,27		mmol/l	
glucose	4,11	7,94	5,5	mmol/l	
Total protein	52	82	70	g/l	
albumine	23	40	35	g/l	
sodium Na+	144	160	130,4	mmol/l	
potassium K+	3,5	5,8	6,29	mmol/l	
calcium	1,98	3	0,98	mmol/l	
chloride	109	122	104	mmol/l	
pH	7,3	7,45	7,282		
ACTH-stimulation test					
0h		cortisol	<2	ng/ml	
1h		cortisol	<2	ng/ml	

PREVIOUS INFORMATION:
habitus: depressed
heart rate: 88/min
capillary refill time 3 sec.
able to walk with assistance

Dog, 6 years old, crossbreed, male

- inappetence for 2 days
- vomiting
- diarrhoea if fed with dried food

Give maximum of five differential diagnoses, one in each box

Appendix 1 continued

Survey on veterinary internal medicine diagnostics

Questions marked with a * are required

* CASE 3: Signalment and anamnesis:

Dog, 4 years old, Small Munsterlander, male-castrated

- 1 yr ago anemia, azotemia after nephrectomy due to ectopic ureter
- renal values prior to surgery were within reference ranges
- erythropoetin was low
- SDMA values elevated
- PCR Anaplasma, Ehrlichia canis, Babesia canis, Mycoplasma hemocanis negative
- cystitis treated with amoxicillin (no current problem)
- current medication: omeprazole
- faeces were soft from time to time, over the last years now waxing and waning history of vomitus and diarrhea
- dewormed and vaccinated on regular base
- no travel history
- water intake and urinary output unremarkable

Give maximum of five differential diagnoses, one in each box

Survey on veterinary internal medicine diagnostics

Questions marked with a * are required

* CASE 3: Interview and physical examination:

chronic azotemia
anemia
vomiting
diarrhea
heart rate 60/min
nutritional status: slim

PREVIOUS INFORMATION:
Dog, 4 years old, Small Munsterlander, male-castrated

- 1 year ago anemia, azotemia after nephrectomy due to ectopic ureter
- renal values prior to surgery were within reference ranges
- erythropoetin was low
- SDMA values elevated
- PCR Anaplasma, Ehrlichia canis, Babesia canis, Mycoplasma hemocanis negative
- cystitis treated with amoxicillin (no current problem)
- current medication: omeprazole
- faeces were soft from time to time, over the last years now waxing and waning history of vomitus and diarrhea
- dewormed and vaccinated on regular base
- no travel history
- water intake and urinary output unremarkable

Give maximum of five differential diagnoses, one in each box

Appendix 1 continued

Survey on veterinary internal medicine diagnostics

Questions marked with a * are required

* CASE 3: Laboratory findings and other examination results:

Abdominal ultrasound:
left kidney absent, right kidney with minimal hyperechoic cortex
left adrenal gland 0,7 cm, right adrenal gland not visible

Laboratory results					Alternative
	Reference values		Results	Unit	Unit
leukocytes	5,05	16,76	12	K/µl	E9/l
erythrocytes	5,65	8,87	4,52	M/µl	E12/l
hemoglobin	13,1	20,5	10,2	g/dl	
hematocrit	37,3	61,7	28,9	%	
MCV	61,6	73,5	63,9	fl	
MCH	21,2	25,9	22,6	pg	
MCHC	32	37,9	35,4	g/dl	
thrombocytes	148	484	301	K/µl	E9/l
MPV	8,7	13,2	15,6	fl	
neutrophils	2,95	11,64	5,17	K/µl	E9/l
lymphocytes	1,05	5,1	5,75	K/µl	E9/l
monocytes	0,16	1,12	0,35	K/µl	E9/l
eosinophils	0,06	1,23	0,47	K/µl	E9/l
basophils	0	0,1	0	K/µl	E9/l
reticulocytes	10	110	52,7	K/ul	
ALT	10	125	14	U/l	
GlDH	0	10	1,4	U/l	
ALKP	23	212	10	U/l	
bilirubin	0	15	2,22	umol/l	
urea	2,5	9,6	10,4	mmol/l	
creatinine	44	159	147,6	umol/l	
cholesterine	2,84	8,27		mmol/l	
glucose	4,11	7,94	4,4	mmol/l	
Total protein	52	82	59	g/l	
albumine	23	40	2,4	g/l	
sodium Na+	144	160	140,8	mmol/l	
potassium K+	3,5	5,8	4,19	mmol/l	
calcium	1,98	3	1,14	mmol/l	
chloride	109	122	118	mmol/l	
pH	7,3	7,45	7,442		
Urinalysis					
specific gravity	1,016	1,06	1,022		
pH	5	7,5	9		
leukocytes			+		
otherwise unremarkable					
ACTH-stimulation test					
0h		cortisol	<2	ng/ml	
1h		cortisol	<2	ng/ml	

PREVIOUS INFORMATION:

chronic azotemia
anemia
vomiting
diarrhea
heart rate 60/min
nutritional status: slim

Dog, 4 years old, Small Munsterlander, male-castrated

- 1 year ago anemia, azotemia after nephrectomy due to ectopic ureter
- renal values prior to surgery were within reference ranges
- erythropoetin was low
- SDMA values elevated
- PCR Anaplasma, Ehrlichia canis, Babesia canis, Mycoplasma hemocanis negative
- cystitis treated with amoxicillin (no current problem)
- current medication: omeprazole
- faeces were soft from time to time, over the last years now waxing and waning history of vomitus and diarrhea
- dewormed and vaccinated on regular base
- no travel history
- water intake and urinary output unremarkable

Give maximum of five differential diagnoses, one in each box

Appendix 1 continued

Survey on veterinary internal medicine diagnostics

Questions marked with a * are required

* CASE 4: Signalment and anamnesis:

Dog, 8 years old, Chihuahua , female-neutered

- 2017 acute kidney injury, kidney values within reference range or slightly increased the last years
- on renal diet since 2017
- since 5 days reduced food intake
- since 4 days vomitus
- since 1 day progressive lethargic
- food intake - none since 2 days
- water intake - reduced
- feces - normal
- urinary output - normal (owner opinion)
- no travel history
- regularly dewormed and vaccinated

Give maximum of five differential diagnoses, one in each box

Survey on veterinary internal medicine diagnostics

Questions marked with a * are required

* CASE 4: Interview and physical examination:

chronic kidney disease (CKD)
T: 37,0°C, heart rate: 80/min, mucous membrane: dry sticky

PREVIOUS INFORMATION:
Dog, 8 years old, Chihuahua , female-neutered

- 2017 acute kidney injury, kidney values within to slightly increased the last years
- on renal diet since 2017
- since 5 days reduced food intake
- since 4 days vomiting
- since 1 day progressive lethargic
- food intake - none since
- 2 days water intake - reduced
- feces - normal
- urinary output - normal (owner opinion)
- no travel history
- regularly dewormed and vaccinated

Give maximum of five differential diagnoses, one in each box

Appendix 1 continued

Survey on veterinary internal medicine diagnostics

Questions marked with a * are required

* CASE 4: Laboratory findings and other examination results:

Abdominal ultrasound
both kidneys: with severely reduced corticomedullary distinction; moderate hyperechoic cortex and irregular surfaceadrenal glands: 0,4cm
gallbladder: severly filled with moderate amount on sludge
liver: homogenous, moderately hyperechoic

Parasitological examination (feces) - no findings

Laboratory results					Alternative
	Reference values		Results	Unit	Unit
leukocytes	5,05	16,76	7,51	K/µl	E9/l
erythrocytes	5,65	8,87	6,61	M/µl	E12/l
hemoglobin	13,1	20,5	16,1	g/dl	
hematocrit	37,3	61,7	44,4	%	
MCV	61,6	73,5	67,2	fl	
MCH	21,2	25,9	24,4	pg	
MCHC	32	37,9	36,4	g/dl	
thrombocytes	148	484	347	K/µl	E9/l
MPV	8,7	13,2	9,6	fl	
neutrophils	2,95	11,64	6,23	K/µl	E9/l
lymphocytes	1,05	5,1	8,26	K/µl	E9/l
monocytes	0,16	1,12	0,3	K/µl	E9/l
eosinophils	0,06	1,23	0,03	K/µl	E9/l
basophils	0	0,1	0	K/µl	E9/l
ALT	10	125	14	U/l	
GIDH	0	10	3	U/l	
ALKP	23	212	89	U/l	
bilirubin	0	15	3,59	umol/l	
urea	2,5	9,6	51,4	mmol/l	
creatinine	44	159	925,5	umol/l	
cholesterine	2,84	8,27		mmol/l	
glucose	4,11	7,94	5,4	mmol/l	
Total protein	52	82	50,6	g/l	
albumine	23	40	26,8	g/l	
lipase (DGGR)	0	250	587	U/l	
sodium Na+	144	160	136,7	mmol/l	
potassium K+	3,5	5,8	6,32	mmol/l	
calcium	1,98	3	0,84	mmol/l	
chloride	109	122	102	mmol/l	
phosphate	0,85	2	8,18	mmol/l	
pH	7,3	7,45	7,203		
Urinalysis					
specific gravity	1,016	1,06	1,016		
pH	5	7,5	5		
protein			500		
blood			++++		
bilirubin			+		
erythrocytes			+		
bacteria			no		
UPC			7,1		
blood pressure					
systolic 109, diastolic: 78, mean: 88					
systolic: 102, diastolic 94, mean: 84					
systolic: 130, diastolic: 64, mean: 86					
systolic: 122, diastolic: 75, mean: 93					
Cortisole					
	24,8	124,2	275,9	nmol/l	

PREVIOUS INFORMATION:
chronic kidney disease (CKD)
T: 37,0°C, heart rate: 80/min, mucous membrane: dry sticky

Dog, 8 years old, Chihuahua , female-neutered

- 2017 acute kidney injury, kidney values within to slightly increased the last years
- on renal diet since 2017
- since 5 days reduced food intake
- since 4 days vomiting
- since 1 day progressive lethargic
- food intake - none since
- 2 days water intake - reduced
- feces - normal
- urinary output - normal (owner opinion)
- no travel history
- regularly dewormed and vaccinated

Give maximum of five differential diagnoses, one in each box

Appendix 1 continued

* Did you wrote one or more differential diagnoses that you have NEVER seen in practise?

- ◯ Yes
- ◯ No

* Did you use any external sources of information when answering the questionnaire? (It wasn't forbidden)

- ◯ Yes
- ◯ No

Done

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Permission from the survey participant
Survey data and results were used anonymously with the permission of the participant.

conflict of interest

- The author confirms the absence of a conflict of interest. The findings were not affected by the tech company GekkoVet LLC The company supported the present study by donating licence to use GekkoVet CDSS for the study. License was available to all veterinary students for free at the time of writing this thesis.

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