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How Lab Results Guide Paramedic Decision-Making in Acute Situations

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ABSTRACT

In emergency medicine, paramedics must quickly and accurately make therapeutic and transport decisions. Laboratory and test findings are critical for guiding paramedic decision-making in acute situations before hospital arrival. Among many interrogated tests, serial blood glucose tests effectively ruled out hyperglycemic and hypoglycemic events, which required fast transport. Interrogated lab results provided valuable additional info such as potential prevalence of cardiac disease and renal failure, along with pre-existing laboratory findings. This study uniquely investigates how specific lab results impact paramedic decision-making. Prior studies identified lab results that could be interrogated and correlated the detection of abnormal lab results with therapeutic and transport decisions. However, the agent and informants in these investigations were either the healthcare provider or the hospital. Thus, while lab results that could be interrogated were identified, the subsequent decision-making utilized lab results interrogated by the paramedics were under-explored. This limitation can be partially ascribed to the inherent difficulty in accessing paramedic data in the emergency medical service sector and confidentiality concerns regarding patient safety and privacy. However, it also remains to be understood how this knowledge affects paramedic treatment and decision-making.

Neuroscience and cognition perspectives of framing and embodiment remain under-explored in emergency medical services. This study uncovered how lab results outcome, type of interrogated lab results, and biomedical portrayals of interrogated lab results affect paramedic decisions on patient management and transport. The research goal extends beyond examining how lab results affected paramedic communication and consultation with off-site medical personnel. It is also concerned with how this affected paramedic patient management, including further treatment and diagnostic testing, and transport decision-making. Prior studies in emergency medicine mainly focus on knowledge which assists decision-making, under-explored in general. Prior studies in

emergency medicine similarly mostly investigated the role of knowledge in decision-making. For example, one study examined how communicative foresight affects emergency department resource allocation decision-making, while another study investigated how the temporal foresight of staff constraints in an emergency department affects decision-making. Prior studies in emergency medicine have also investigated how decision-making is affected by emotions.

1.2 **Keywords (only 8 keywords)**

Paramedic, Pre-hospital laboratory tests, Clinical decision support, Laboratory results, Diagnosis, Decision-making

1.3 1. Introduction

Intensified pre-hospital emergency care services and technological advances in emergency medicine and pre-hospital care have made the work of paramedics more complex. Patients' chances of recovery from life-threatening injuries and diseases depend on the quality of decisions and actions made at the scene. Decisions made in the field must be forwarded to other medical institutions using a limited number of information sources and in a very short time. Examining the feasibility of laboratory results for triaging patients on arrival at the emergency department (ED) can improve attention to rapid health deterioration. This paper aims to explore how paramedics within a specific pre-hospital emergency care organization interpret and utilize on-scene laboratory results in triaging patients in severe acute situations (Koivulahti et al., 2020).

Despite restrictions for research purposes, this research focuses on how laboratory results influence triaging by paramedics. Triage against pre-determined conditions would guide their interpretation of results. Ideas of priority were evaluated using resources and time in a grounded theory study based on a patient and actuary's viewpoint. The data were collected and analyzed using qualitative semi-structured interviews. A total of 15 paramedics, professionals who received a bachelor's degree through three years of academic education, were interviewed individually. It took two to two and a half hours with each paramedic and was audio-recorded and transcribed verbatim. The qualitative data were analyzed using thematic analysis through inductive and deductive approaches. Demographic data were analyzed using quantitative methods (mean, median, and percentage).

Complementary data in the form of one semi-structured interview with the head of the pre-hospital organization and approximately 400 pages of documents were collected and analyzed for triangulation and contextualization. This article offers state-of-the-art knowledge from paramedics with bachelor's degree educations on how they interpret and utilize on-scene laboratory results. In addition to medication errors and the development of a series of automated text messages, sensitive triaging situations in which immediate attention is warranted are presented herein.

1.4 2. The Role of Paramedics in Emergency Care

The purpose of the Emergency medical services (EMS) is to assess patients suffering from acute illnesses or injuries, provide the proper treatment, and transport patients to a definitive care if necessary. In order to fulfill these extreme expectations, paramedics generally must be able to estimate the condition of patients, and to already establish a preliminary diagnosis (PD) in order to initiate appropriate care in the field, or during transportation. The PD is an interim stage on the

way towards an accurate diagnosis made by a physician. However, the PD has an essential role in directing the care and judging the urgency of the transportation. The paramount characteristics of the work of paramedics have become more complex due to the increase in emergency calls, demographic changes and new healthcare technologies, which enable intensive pre-hospital treatments. Because of these facts, emphasis has now been placed on the clinical decision-making skills of paramedics to guarantee both the safety and the quality of care. Thus far, it has been mostly addressed how paramedics as care providers evaluate the care that they deliver, whereas their PDs themselves have been somewhat neglected. Nevertheless, the determination of an accurate PD has implications for the quality and safety of care and for improving patients' outcomes. On the contrary, making a wrong PD can lead to inadequate treatment or adverse events for patients.

Most studies are conducted on paramedic populations, many of which concern the agreement of PD algorithm-based diagnoses (Koivulahti et al., 2020). Furthermore, the results of these studies vary widely, even though similar approaches are used. Investigated the accuracy of PDs made by paramedics and reported an overall accuracy of up to 70%. Two studies evaluated paramedic PDs in respiratory emergencies and found that when paramedics determined the underlying etiology in breathing difficulties, they had an overall agreement of 81.1%. In a preliminary diagnosis task, they reported a brute force accuracy of 64% in datasets. Other studies show that an ST-segment elevation myocardial infarction (STEMI) was detected with reasonable accuracy. Moreover, paramedics with a longer education were better at clinical decision-making than those with less education. However, there are no international standards or regulations for paramedics or prehospital emergency care nurses.

1.5 3. Understanding Lab Results

Lab tests create various parameters about the state of a simulation in question. This creates countless opinions and ranges as well as interpretative freedom. However, to clarify facts with science, it must be understood that this freedom could be regulated in the future with respect to the testings and the outcome ranges. The blindness nature of lab test applications does not create the same fate. Implemented tests have limitations as well as the ranges and the breath of the analysis connects a chance to elaborate the range of interpretation (Prottengeier et al., 2017). Moreover, since the outcome is relative and interactive things like illumination and blood gas, after time, mechanical shred states must be taken into consideration. One example could be the application of neutrophil granulocyte percentage for diagnosing infections. If the blood sampling of the patient is more than an hour without any refrigerated storage after the taking, this lab value does not serve a significance conclusion, since the cells of the blood start to petrify and the nucleuses rupture.

The outcome of lab tests needs a grand focalisation to combine all the parameters and interpret and reason. However, lab tests still create figures despite all these limitations, but since there should be a better understanding of the exact interpretation, a study is designed to determine the reliability of few basic parameters for being immediate tested either on the red ambulances or by clinicians instead of laboratory researches. and codes modeled two random patients with

hyperpotasemia, hyperglycemia, and metabolic acidosis. To create a safe and elite approach, the discussion on diabetic ketoacidosis diagnosis is limited. A hyperglycemic but neither hyperpotasemic nor metabolic acidic mannequin would suffice to guarantee a fact that they would be certain.

The expert should serve the lab tests guidance argument. Since lab tests emerge extensive result ranges and expand interpretation freedom, they imply much room for unsureness. Hereby, in some medical cases which are mild enough but potentially worsened like in diabetes, diabetic ketoacidosis is relatively rare but once occurred is life-threatening, lab tests should be relied least at least in the acute conditions. Additionally, much freedom includes the chance that the informative windows should either be lengthened or shortened; the intelligence of them determines their pre-existence. Output of lab tests made a super fast and emergent decision a rare one. would Quadratic integrated lagged first seven values and forecasted whether the active, acute basis for democracy guard is sufficient or not to keep necessary prevention.

3.1. Types of Lab Tests

In most cases, paramedics can begin resuscitation without blood tests. New laboratory tests using POCT equipment make crucial contributions to emergencies, improve the primary assessment, and aid in decision-making (Prylińska et al., 2019). Since they are still not commonly used in prehospital emergency care, special emphasis lies in the use of laboratory tests offered on POCT equipment. However, several preanalytic problems such as contamination, blood sample stability, and hemolysis have to be prevented. Education of personnel, an established online lab system, and cooperation with a laboratory specialist contribute to preventable problems. Most commonly used tests and their use cases will be presented (Prottengeier et al., 2017).

Originally laboratory tests were performed in stations in hospitals. Tests on blood samples often took place in those places. The benefit of the examination lies in gaining information about an illness and deciding on further treatment. Nowadays laboratory diagnostics is performed in devices located directly on the floor or in the ICU. Their results contribute to instant decision-making and treatment. Intensive Care Units of hospitals commonly use the POCT equipment. The demands for POCT equipment use in prehospital treatment are growing. The information obtained from these tests influences an emergency physician’s treatment decision.

Test equipment has undergone remarkable development in past years. Measuring principles have been redesigned and new test devices were developed. There is a difference in tests and scope of detection between these systems. POCT equipment allows for the measurement of blood gases, electrolytes, metabolites, proteins, and ionized calcium. This equipment directly benefits emergency decision-making in a prehospital situation. Nevertheless, devices offer examinations based on approaches of antigen-antibody binding. Finally, pseudo POCT devices were developed.

3.2. Interpreting Lab Values

The ability to interpret lab values correctly and efficiently is vital to the delivery of quality prehospital care. Although there is limited availability of point-of-care lab results in the out-of-hospital setting, lab data will continue to be collected and integrated into patient records ahead of paramedics’ arrival for some time. The lab values available from hospitals can provide valuable

context to paramedic decision-making and are better used on an individual case basis than strictly as a predictive tool across the board.

Given the continuous influx of new lab data, it is paramount that paramedics are able to interpret lab values swiftly. In particular, to avoid signal loss among the noise, focus should be trained on understanding the relevance of values considered to have the most clinical import to paramedic care. These lab values can generally be classified into two categories: ones associated with urgency and those typically associated with pathology. Values indicating the presence of urgent needs for care should top the list of values to be understood vigorously. If a patient is found to have a profoundly abnormal lab result on arrival at the hospital, then that value and the related urgency of its interpretation should be well and deeply understood beforehand by paramedics, as it could potentially guide rapid decision-making. Such lab values include those pertaining to blood gas status and gas exchange, renal function, and coagulopathy or other acquired coagulopathies. Values indicating the presence of pathology should also be understood comprehensively, as knowledge of a patient's pathology is required for the safe and mindful delivery of care. Lab values classically associated with pathology would include elevated white blood cell count; elevated troponin; elevated ST-PAP estimated LDH; elevated AST; elevated INR; low or low-normal phosphorus; low or low-normal platelet count; low creatinine; low or low-normal sodium; and low or low-normal total T3/T4.

Understanding how lab values vary between demographics and clinical profiles is also essential when utilizing prehospital lab results, as lab values must always be interpreted within the context of a patient's demographics. Many lab values can vary widely between different age cohorts or triads; sexes; health statuses; pregnancies. Only minimal data on patient demographics is typically provided from the hospital. As a result, lab values should always be interpreted within the overall context of demographics and only after a gender-age-health profile has been created.

1.6 4. The Importance of Timely Lab Results

One of the most critical processes during emergency cases is obtaining relevant laboratory data, typically via laboratory tests performed by laboratory technicians in a clinical setting. These results are subsequently relayed to the responsible medical doctor, allowing for timely detection of any abnormalities in the obtained data. For emergency transport, lab tests conducted in an emergency room (ER) of a hospital are forwarded to field paramedics via cellular phone calls, followed by an intelligent decision-making process to determine the best acute strategy based on the lab results.

Timely access to relevant laboratory tests can enhance trauma care. All critical laboratory values in the field of hemostasis should be reported to the clinic to avoid false results. Several studies have characterized the timeliness of reporting critical laboratory values as a quality indicator in pathology and laboratory medicine. A critical laboratory value is defined as a laboratory result constituting an unacceptable risk to a patient's well-being unless some timely corrective action is taken (Sergi, 2018).

In hospitals and clinics, due to the often-urgent nature of laboratory tests, and especially this group of tests, it is crucial that patients receive timely lab results. If a critical test result is not promptly relayed to a clinician, there is a risk of a medical error occurring, which can lead to the incorrect

treatment option being provided. In this respect, the importance of lab results should not be overlooked in clinical decision-making.

4.1. Impact on Patient Outcomes

Healthcare professionals must rely on timely laboratory results to make critical clinical decisions. Paramedics are commonly the first HCP in emergency situations and make important triage decisions based on clinical history as well as preanalytical diagnosis. Hence, prehospital laboratory tests could supplement this knowledge and support paramedics in crucial decision-making. However, little is known about the effect of the time of prehospital laboratory results on patient outcomes. The suggested underlying concepts play an important role in improving the effectiveness of EMS. The innovations in terms of the service, such as a broader range of workflow options, provider-specific services, KPIs, and parameter sets, are crucial in addressing the complexities of the prehospital emergency response.

It is assumed that PHLR's influence on patient outcomes is moderated by both the time of prehospital receipt and the availability of test results in the receiving hospital. In the heart-thoracic pathologies and coding of acute myocardial infarction groups, there is a clear improvement in the patient outcomes, measured in terms of mortality and morbidity. These findings could be justified by evidence indicating that acute coronary artery occlusion leads to secondary myocardial damage that affects several biological mechanisms. An early intervention or treatment strategy is crucial in such cases and justifies the emergency use of prehospital laboratory tests. In the respiratory pathologies group, the improvement in patient outcomes is limited. In cases of suspected pulmonary embolism, the implementation of mass screening has led to more missed intermediate risk patients, leading to substantial discordance between clinical assessment and diagnostic tests.

In the set of groups on which this study takes a more detailed look, a range of borderline effects is found. The available measurement of patient outcomes includes personal outcomes such as mortality and morbidity, recanalization and complication therapy, procedure outcomes such as duration of hospitalization and CT scan delay, and process outcomes such as admission to the ICD pathway and one-day turnaround rate.

4.2. Challenges in Laboratory Processing

The ideal standard committee on laboratory critical results, such as a multidisciplinary clinical advisory group of senior staff, which meets regularly together with representatives of all disciplines involved, is mentioned often in theory, but hardly any laboratory can meet these criteria (Lam et al., 2016). Currently, there is no national body in many countries promoting, supporting, or enforcing the development of critical-list advisory groups. Clinical staff representatives vary in competence from institution to institution and discipline to discipline. Laboratory pathologists have little or no control of in-hospital clinical laboratory results forwarding and distribution systems. In hospitals with various disciplines, often strong contingents of privately owned pathology services, laboratories have been built with competition as the main objective. No one has a complete overview of which tests are executed by which laboratory but all can and attempt to sell low prices. Because of this situation, few laboratories can pinpoint the scope of their practice. Consequently, none can develop comprehensive alert lists either. Currently, many

practice groups establish a so-called minimum list, without any plans as to how the rest of critical cases will be handled, or how to proceed with defining and importing the critical results of other tests.

The results from new technology don't appear on the screen during the usual interpretation process. Current laboratory information systems often seem incapable of forwarding the critical results of new test systems when these systems are integrated into a routine laboratory. Novel analyzers can generate a lot of new results weekly, which have to be recognized and added to the routine interpretation system. Time constraints often render it impossible to review the mounting information. Moreover, this type of information is usually recorded as a continuous string of numbers without any real-time information concerning the previous samples values or possible violations of alert values. Because of this, the critical values defender program has a lot of information backlog and some analyzers are only reviewed for alert values once or twice per week. Because of this, some elements seem to be lacking in the front-trace efforts to implement the recommendation of the Expert Panel. Proper and comprehensive implementation of guidelines and standard operational procedures in hospitals needs concerted efforts, although the better part of this is the laboratory's task. However, laboratories can't implement what can't be achieved with assistance from the clinical staff. Only a clear statement of intention by management can provide the necessary commitment.

1.7 5. Integrating Lab Results into Paramedic Protocols

Lab results obtained in the emergency department (ED) are an important source of information, which can be used by clinicians to perform diagnostic and therapeutic decision-making processes. Nevertheless, lab results are provided in the ED only after a certain period of time and are not available for paramedics in prehospital environments. To provide paramedics with access to lab results generated in facilities of advanced care and support decision-making, first, lab results should be captured in emergency care strategies on the basis of a well-designed algorithm, delivering those to paramedics in prehospital environments in real-time, and integrating those lab results into paramedics' protocols. This section focuses on the third phase and should provide an overview of how prehospital lab results can be integrated into protocol-based decision-making.

Interpreting lab results sent from advanced care facilities to paramedics can be quite different from coding only decision-making natively performed by paramedics in previous prehospital care strategies. There may not be sufficient knowledge for elaborating a reliable implementation of those lab results. The integration to be performed in this phase is limited to protocol-based paramedic decisions that have been realized by coded decision-making and are deemed to be useful. These protocols should be extended by abstracting further and specific rules for the interpretation of lab results in the existent coded protocols. Only the application of further specialized rules is intended, and the remaining coded decisions should be kept unchanged.

In the first substep of that stage, protocols based on decision satisfaction are chosen to be extended. It is based on an assumption that these protocols contain all decision-making processes performed and therefore maximal information necessary for interpreting lab results. Protocol ontology determined, consisting of protocol classes and their attributes. A coding scheme should be

developed consisting of a set of parameters determining paramedic decision codings. A well-designed parameter coding scheme is key to the successful encoding of protocol-based decision-making in prehospital care scenarios.

5.1. Standard Protocols

Paramedics must identify and assess patients in acute situations, often relying upon standard guidelines (A Colbeck et al., 2018). CPGs guide the treatment decisions of paramedics, consisting of 'aspects' each with multiple 'decisions'. The aspect of interest in this study is 'clinical investigations and laboratory tests', with the following decisions: 1) Sending bloods or urinalysis to the lab; and 2) Organising the lab test, and 3) Documenting properly. This aspect includes two 'decision points': A strict YES/NO test. A 'YES' decision leads the CPGs to recommend the activation of the laboratory; a 'NO' decision leads to alternative paths and articulations. Once an investigation has been ordered and disciplined pathways are actioned, laboratory tests cannot (and should not) be undone.

It was described how non-expert professionals often treat evidence inconsistently with standard guidelines. However, paramedics' practice conforms somewhat to the standard guidelines, suggesting that they are well-educated and trained. A surprising number of off-hand decisions were noted (Sanello et al., 2018). Book-keeping of decisions was poor compared to all other aspects, indicating that documentation may not be part of evidence grounds. Standard clinical decisions were simple YES/NO decisions. Failure to recall a decision at these momentous instances was frustrating and, while some lab results 'stick to mind', later revaluation of these impossibly complex chains led paramedics to over-abstractive and abstract reasoning.

Other decisions clustered as an articulated breeze (compared to expression), owing possibly to appeal-based intervention in the elaboration of clinical detail of attending decisions. Answers to abstracted questions framed globally or solution-discipline zones proved particularly recessionary, perhaps due to indecision or intra-experience idiopathy of knock-on conclusions. Conversely, many initially unsought particulars (i.e., emergent properties) were cited upon reflection. These in context-intruded mechanisms were diverse and exceed the recounted frameworks of expertise as well as the individual scope of knowledge in hindsight, suggesting that control over professional knowledge sought abduction. Though unseen, both seen and unseen actions likely exercised co-implicatively on the decision-making process.

5.2. Case Studies of Protocol Application

In order to clarify the usefulness of protocols in the clinical prehospital setting, case studies of paramedic decisions made in suspected myocardial infarction and thoracic aortic dissection situations, known for displaying diverging test result patterns and therefore diverging protocols, are presented (Andersson Hagiwara et al., 2013). The two cases are described with attention to the paramedic assessments and lab tests performed, as well as a comparison of the presented contexts. After this, a discussion is provided where the implications of the case studies for protocol design, implementation and usage in the prehospital setting are addressed. The case studies show how deviation from strict protocol adherence is motivated by information derived from the lab test applied. In essence, the lab results generated information beyond the raw lab tests values that

marginally or entirely rendered elements of strict protocol adherence unnecessary. This resulted in context-specific adjustments of protocol adherence that led to a better foundation for guiding expert-driven care in the prehospital clinical situation, than in the case of strict adherence to the given protocol alone. Although this supports the usefulness of the deviation from strict protocol adherence, it also questions the design of the protocol as it could not address several aspects that the paramedics considered important to ensure a high standard of care. The proposed protocol derived from the entire study indicated that the basic structure of the designed lab-result-driven paramedic protocol proved to be useful in the prehospital clinical context. However, to meet the users' needs and ensure high compliance with its contents, adjustments to address the lessons identified in this study are necessary, either by explicitly providing strategies for when to deviate from the contents, or by enabling flexible adherence to its contents among well-educated users. In the case studies, the design and a subsequent evaluation of the usefulness of lab-result-driven paramedic triage protocols to guide paramedic decisions in acute situations, were presented and discussed. The purpose was to elucidate how the usefulness of protocols is contingent upon the applicable knowledge representations in selection and adherence inclinations among users, as well as how protocol design can accommodate these contingencies.

1.8 6. Decision-Making Models for Paramedics

The first study aimed to contribute to organized and structured decision-making by adapting an existing model (Häske et al., 2019). One specific goal was to explore the model's use and sequencing in paramedic teams when signs of indecisiveness were observed. Another goal was to determine whether some decision-aiding questions were often neglected, giving rise to 'blind spots' in arriving at decisions. Finally, thorough and structured decision-making was examined in relation to argumentation, uncertainty, and risk assessment in medical emergency rescue situations and how laboratory findings were used in the clinical decision-making process. The second study sought to propose a practical conceptual mental model for correctly interpreting and managing acute undifferentiated complex situations when managing medical emergency psycho-social factors (Hammad Al-Azri, 2020). The focus was on the cognitive strategies used by experienced emergency care providers followed by difficult short cases.

Emergency situations stress workers and speed up decision-making. This condition sometimes leads to decision errors and treatment mistakes. Different aspects can affect decision-making, but the related studies to date have largely overlooked the use of these aspects as general frameworks for correctly interpreting and managing emergency situations instead of one-dimensional cognitive strategies. The two studies sought to find ways to maintain high-speed correct decision-making. Decision-aiding versions of previous models to assist speedy decision-making were also examined. The use of informed knowledge of decision-making principles by emergency care providers was investigated, together with the circumstances necessitating the use of such knowledge and the resulting decision-making processes.

Decision-making was examined in regard to the effect of ambulance lab examination and imaging tests on paramedics' decisions for treatment. The question was also examined whether there was

a tendency for different decision-making methods according to the type of tests and decisions. The two studies hoped that investigators and practitioners would find the results and methods useful.

6.1. Evidence-Based Practice

We followed the recommendations made by various organizations that performed systematic reviews and meta-analyses regarding treatment interventions (Sanello et al., 2018). Additional literature searches were performed through PubMed from 1966 to 2017 for each question. This search yielded 42 articles, only five of which were published in English and pertinent to the topics identified by the EMDAC subcommittee. Levels of evidence (LOE) were assigned and the recommendations graded based on the process of creating clinical policies. Classes of evidence were assigned to diagnostic, therapeutic and prognostic questions based on study design, including data collection methods, randomization, blinding, outcome measures and generalizability. LOE I consisted of randomized controlled trials, prospective cohort studies, meta-analysis of randomized trials or clinical guidelines/comprehensive reviews. LOE II consisted of nonrandomized trials, retrospective studies. LOE III consisted of case series, case reports, and expert consensus. After assigning LOE, these were translated to clinical grades of recommendations. Level A Recommendations are based on either one or more LOE I studies or multiple LOE II studies. Level B Recommendations are based on either one or more LOE II studies or multiple LOE III studies. Level C Recommendations are based on only poor quality or minimal LOE III studies or consensus. No Recommendation was given when only preliminary data or no published evidence exists. Recommendations were also withheld when studies show conflicting data. After providing recommendations for both diagnostic and treatment interventions, the current AMS protocol from the 33 agencies were reviewed for consistency with the recommendations (Prottengeier et al., 2017). Pre-hospital care of patients with a chief complaint of AMS can occur due to a number of causes which have often been grouped by etiology for ease of review. Approach to similar complaints in the pre-hospital environment should focus on recent evidence, prioritization by potential for harm and where EMS providers have the skill for timely intervention. This review details the strengths of various pre-hospital evaluations employed through initial assessment, problem focused history and physical examination, laboratory testing and pre-hospital pharmacologic intervention.

6.2. Clinical Decision Support Systems

Clinical decision support systems (CDSS) are systems designed as computational or technological product that help physicians and nurses to make better informed clinical decisions and improve patient safety (Beatriz Walter Costa et al., 2021). The implementation of a CDSS in a health care environment requires integration of the system into the pre-existing dataflow, computational infrastructure, and clinical procedures. Hospitals commonly use enterprise software for data administration and processing. Even in this software there exist several modules supporting different tasks. The platform provides a Business/Data Warehouse (BW) module that synchronizes and standardizes data structures from different systems. This module is the data source for the CDSS and the algorithms used for specific evaluations.

Laboratory diagnostics is a highly standardized domain and an important source for clinical decision making. Results are delivered from the laboratory with respect to predefined thresholds and rules, resulting in orders of magnitude more information than in the past. Many to a vast majority of results arriving in the clinical ward are numeric and most importantly interpreted with respect to pre-defined thresholds. This allows for a set of rules for the evaluation of analyzed laboratory results to be defined by medical specialists like pathologists, chemists, researchers of the university or hospital, or educated nurses. This creates a context for a CDSS based on programming logical with the knowledge that there exist a master sheet with ever laboratory methods (parameters) and laboratory biomarker and a sheet with rules that comprise thresholds that are evaluated to thousands of numeric results in each cycle.

Systems that evaluate laboratory results either find distinctive conditions or for specific diseases or purposes have been reviewed. Since a study on laboratory results in 1991 it is proposed that most improvement in patient safety could be attained by alert systems that evaluate results before reporting. As there are systems developed by a few commercial institutions, there are yet no systems capable of working with different laboratory biomarkers in parallel (CDSS context) and identifying complex laboratory assemblies. The problem of alert fatigue should be addressed in the implementation of a CDSS. Laboratory measurements are patient specific and in contrast to imaging or other modalities the results show a good balance between over alerting and under alerting in a CDSS context.

1.9 7. Communication of Lab Results

Directly communicating significant results which require timely clinical attention is a universally acknowledged role of the pathology laboratory. Accreditation standards from professional societies and regulatory bodies formalise the requirement for laboratories to manage high risk results, but offer very general guidance on how this should be achieved. There is evidence of wide differences in practice between laboratories both internationally and within the same country. These differences are seen in all aspects of high risk results management including the nomenclature and definitions used; which critical tests and thresholds are included in alert tables; specification of who can receive results and by what mode of communication; what information should be conveyed with the result; how receipt of the result is acknowledged; escalation protocols for failed attempts at communication; and how communication events are recorded (Lam et al., 2016).

It is best practice to ask the clinician at the time of communication about how quickly they will act on the information, but it is uncommon for this dialogue to take place unless specifically anticipated in the routine protocol. There are many, mostly unanswered, examples of policy decisions on how to handle outliers. If a sick patient is not seen within 5 minutes, or at all, what happens next? If both physician and nurse have been informed but no further action is taken, when should the issue be referred to a supervisor? When rummaging through the paperwork to find a forgotten abbreviation, what is the best course of action? These situations, while rare, demonstrate the need for an open-ended approach to the development of protocols (C. Klatt, 2023).

The majority of the 'doctors' workers made specific comments about their communication protocols that acknowledged the above grey areas that are only rarely addressed in BRS documents. However these comments offered little guidance for others trying to manage the same difficulties. They seemed more concerned with ensuring they had protection from blame should an incident occur. The blind following of protocols without understanding the consequences was acknowledged to make the 'doctor' workers feel clinically irresponsible regarding patients. There were a number of ways in which this approach of simply adhering to a set of rules or a precursor may not safeguard patient safety.

7.1. Between Paramedics and Emergency Departments

When a paramedic becomes concerned over the condition of a patient, a laboratory analysis is often acquired. This will indicate whether any complications may be present within the critical situations in. The targets to study the lab results and predict what kind of complications and diagnoses may it indicate and how the analysis assists a paramedic in deciding either to keep treating the patient or to compose a hand off for the emergency department and further studies. What kind of tests or sequels of tests are opted in various situations and what is their significance for both the medic and the ED. Previous research shows how prehospital teams with a wider selection of operative devices are predicted to act more in line with the guidelines compared to a narrower prehospital test diversity. This may lead to a higher perceived quality of care by paramedics but also fewer erroneous path of care and fewer patient misclassification (Koivulahti et al., 2020). Matched with the lack of knowledge what are the factors in critical situations that nurses relate to the lab results in a similar situation. Furthermore, what kind of lab tests are predicted to assist the paramedic and the diverse manner of analysis presented to the ED.

A need exists for better understanding of how the paramedics obtain situations concerning lab results and a wish to close the gap to the researchers in both nursing and paramedic science. Secondly, a wish to advance the consistency in care for the patients and paramedics is needed whether working in a specified setting or with an out of the normal patient. Focus to instruct the paramedic and ED for further work is likewise represented as a goal for the study. The lab tests in a potential case presented to the emergency department are protective, valuable, and reliable for the assessment of the acuteness and kind of diagnosis of the acute condition. To aid the advance of knowledge several diverse types of cases with various concluding diagnosis have been selected, around ten tests of which are nationwide original Swedish test values for the computation analysis. The paramedic's view to the situation presented examines the reasoning to which understanding the evaluation of the tests and their credence might be of significance in a new learning setting.

7.2. Involving Patients and Families

Involvement of patients and families in decisions regarding treatments, strategies, and course of action offers multiple considerations. Firstly, complex decisions are always preferable regarding a patient. Adult patients who are capable to consent should always be involved in decisions regarding treatments, strategies, and subsequent courses of not only actions but potential alternatives. This involvement offers both the healthcare professionals and community members a consultative and collaborative nature (Azoulay et al., 2014). The shared understanding should be

joint by the patient, family members, and general healthcare professionals. These stakeholders should share a common understanding of the patient's medical situation and decisions that ought to be made. Communication an empathetic consideration with the group of decision makers rural, can often be more enriching for the community and the individual person.

Another consideration regarding involvement of patients and families in decisions is regarding treating the elderly patients. This group is often challenged by great amounts of chronic comorbidities, cognitive challenges, complications with false sense of indecision in existing care, and the need for a joint family treatment. It is ipso facto extremely complex to find out a proper treatment in which situation is 'favorable'. For active care patients would be strong, while for patients who are about to reach death are curative emotions. Above all, the family members are often involved. Prior to decisions about treatments and strategies connotations about what kind of patients would want and should get is usually paramount. Should treatment be performed, provided or even offered? It is vital for ownership of decisions that the wishes, hopes, beliefs and values of the family members are clear in this process. To prepare the recommendation it is found joint consultations with the main healthcare professional team. Concerns, clear questions regarding the wishes of the patients, questions regarding ethics or moral dilemmas can arise during this joint journey.

Articulation of core priorities, appropriate division of roles and responsibilities, and how, when, where and who will involve a follow up to be supportive. Closure actions strengthen involvement. Most healthcare professionals have the feeling that after a semi-structured item panel it is best to ask 'what items do you consider as paramount to close off, before you leave?'. This allows the team to review and, when necessary, to further explain important results. Querying for how, when, where and with whom to share information allow congruence regarding further follow-up with further decisions made. Search for a preferred symbol or something where the family member wants to place or keep a primary topic in this care process enables individual, personalized, and tailored involvement.

1.10 8. Real-World Applications of Lab Results

The paramedics in the European nation Garzia dedicate themselves to delivering the highest standard of emergency medical services, which begins in the field and continues until the patient reaches the hospital. In the field, an assessment of the patient's condition drives the level of care provided. Often there are times inconsistencies in assessment where paramedics are unsure if the patient needs to be transported for further care. In cases like these, a laboratory draw for a random serum biochemistry in routine conditions has the power to limit unnecessary transports to the hospital. With the laboratory tests returning in under 25 minutes and direct reporting to the paramedic over a closed radio channel, it was decided to undertake a study that simulated field conditions to assess how the new process would affect the field results (Prottengeier et al., 2017). Two focus groups sessions with the involved fire brigades were conducted and a risk analysis undertaken. Nineteen biochemistry parameters were selected for the study. After 24 specimens were sampled, temperatures, centrifuged, and reagent principal estimates were tested. Bioreagents were used twice in field mode for 20 laboratory registrations. Results were evaluated based on the

installed upper and lower limits. In the morning, laboratory clinics were also performed. (i) Targeted off-site field laboratory sampling and provision is a viable addition providing relevant results in the out-of-hospital phase of emergency medicine.

In each focus group session, general comments about the device were gathered to identify things the paramedics wanted to see happen first. Feedback from the groups revealed that the best way to implement new tools into the routine would be to integrate direct assessment of a specific biomarker for focus groups into their use of the device. The feedback indicated a desire to test out whether laboratory results provided in the field were as 'valid' as expected normally in farewell laboratories and in the firehouse. (ii) A focus group driven learning sequence on laboratory tests, supported by a handbook-like document, leads to the successful integration of the device into normal work as a new tool.

8.1. Case Examples

As far as there is written literature about early prehospital laboratory tests and point-of-care tests (POCTs), it seems to be focused on laboratory tests carried out by fire departments or emergency medical service (EMS) stations and two scenarios: 1. A "mini-lab" with several possible laboratory examinations carried out at EMS stations and 2. Prehospital laboratory tests examined through the ability to transport blood samples correctly from the accident site to laboratory (Prottengeier et al., 2017).

Currently, the authors´ region is a rural area (400 par. /km²) with many outlying towns. Paramedics who have completed some advanced emergency technician (AET) modules perform ALS interventions within these towns in an anterior train. The hospitals in the area only have one air ambulance helicopter. Point-of-care tests (POCTs) have been instituted within prehospital emergency medical services for 4 years. Reporting and trend analysis focused on the continuous improvement of processes within Emergency Operations Centers and ALS cars. The aim of this litigation is to demonstrate how and why POCT results have a significant impact on paramedic decision-making.

Extreme cases grids used on February 19, 2020, to demonstrate interactions between POCTs and protocols are consequences of simulation-based training on the decision-making behavior of paramedics. These cases are not a result of an event directly affecting patients, nor are they based on real patients, but exclusively on literature.

8.2. Lessons Learned from Field Experience

The paramedic pilot training was well-planned, and the initial design was feasible and provided sufficiently varied results on prehospital laboratory use. The participants made good use of the possibility to discuss the test results and created a good basis for piloting these tests in the field. For many participants, the new situational model introduced new aspects of laboratory observations and possible medical diagnoses that they stated would facilitate making a prehospital decision in the future.

Nevertheless, it was noted that this study had some limitations. While closed questions measure how many paramedics feel that the new tests could change their own practice and how likely they would use them, they do not provide any understanding of why the practice might change.

Therefore, the follow-up testing should have some open questions on changing practice and/or a willingness to change. Another limitation was the participant group. By recruiting only paramedics who had already undergone laboratory training and were interested in the laboratory tests, the group was skewed towards those who were already willing to use tests. To get more varied results, it would be best to include paramedics from both ends of the spectrum, particularly those who did not want to use any tests. Now, such feedback might be lost.

A follow-up phase, including a LC decision-making support system with more tests for broader situations including medical and traumatic issues, and contextualized information would be beneficial, especially if it includes a possibility for the collaborative discussion with medical professionals. Using up-to-date information from the medical domain and integrating medical representation with additional contextual factors would offer the chance for a richer interaction than with static libraries of prior training information (Koivulahti et al., 2020). As such a system could be implemented either on paramedics' own devices or on a screen at ambulances, it could lower the perceived effort of using the suggestions.

1.11 9. Ethical Considerations in Using Lab Results

Laboratory results are indispensable for professional decision-making in acute situations. It remains unclear how paramedics understand the results, what conclusions they draw, and how they act on it. Twenty paramedics were invited to attend a focus group discussion to address this issue. Awareness of the situation and expectancy regarding the laboratory results greatly influenced the paramedic's understanding of results. Used as a threshold or filter for more refined results in less urgent cases, acute values were relevant for drawing conclusions regarding patient stabilization. Expectations of treatment varied with the case (anticipating positive or negative changes) and the lab results (portending either major or modest changes). Due to the rapidity of lab tests and results, it is primarily hospital personnel who are responsible for action decisions based on lab results. Concerns regarding the legality of prehospital blood sampling and transportation significantly influenced the latter. Increasing transport time would change this, as would the rural location of an incident or the absence of a hospital laboratory. Implications for paramedic education are suggested (Prottengeier et al., 2017). Ethical considerations arise from the reliance on lab results to determine clinical decisions, especially in acute situations, such as the use of fingerstick tests for accurate assessments of blood gasses. (Lam et al., 2016). Sensible lab tests lead to justifiable expectations from the paramedics regarding treatment. A fundamental concern exists regarding which actions paramedics are authorized to perform. If on-call lab personnel were never reached and that was a critical international incident, there would likely be no definitive assessment of the patient.

9.1. Patient Consent and Privacy

Patient consent is one element of patient advocacy in prehospital care. Paramedics must consider the need for actions that support patient choices while at the same time recognize situations in which medical decision-making should persist even when there is no formal consent. Consent to prehospital treatment is a legal requirement in most countries and must therefore be practiced as a matter of routine. The emergency medical services (EMS) and hospital-based specialists tend to

have different views on how it is best to handle the need for medical decision-making in urgent situations, according to emphasis on different aspects of patient advocacy as it pertains to consent and privacy (Nordby, 2013). Prehospital care fell more or less in the gap between health care and patient care. Off-screen 'good Samaritan' type of treatments were fairly common and vigilante-type care could probably be considered by the more extreme. Among per definitions more direct types of health care, paramedics would consider all types of implemented treatments and an absolute majority were types of invasive actions (72%).

The axes of need, consent, and completion were, therefore, categories of conduct that were practically unproblematic for paramedics in some cases but very intricate in others. Very few instances of much relevant unconsented patient care were uncovered, yet existing ones were extreme. Many situations including both valid consent and invalid refusals were considered and precluded conduct in works that may be at either end of the completion axis. Such conduct was found to comprise a broad spectrum of methods. The approaches on need would also be ranged over a similar axis, where systems approach was used to divide findings into there subcategories presenting legitimate methods of care related to underlying need. Feasibility of prehospital medical care and treatment of refusal of treatment or further assessment need to be studied.

9.2. Balancing Risk and Benefit

Return delayed lab results may be associated with an increased risk of clinical deterioration in models of out-of-hospital care (Lam et al., 2016). It is reasonable to expect that delayed lab results other than "critical or high risk" would also be associated with clinical deterioration that may necessitate increased levels of care. For example, a paramedic utilizing an oral anticoagulant in the field may administer a four-factor prothrombin complex concentrate if the patient's INR was tested and determined to be above laboratory screening thresholds for therapeutic anticoagulation. If such results were delayed but known prior to hospital arrival, the Paramedic may communicate this risk to ED staff who may implement protocols for additional monitoring, medications, and blood product transfusion in the event of clinical deterioration. A patient with a less proactive management plan but possessing elevated INR results may simply be offloaded as normal. Since results should be communicated verbally to Collaborators, further analysis of how lab results will still be seen by the receiving clinician either before or after offload is warranted.

During original modelling, "delayed" results that reflect the 70 percentile of patient transfer times were included. In practice, partial HCT results are generated well before this time. An alternative models incorporating only 100% complete results supported all quantitative results but did so on a smaller total patient population on account of more conservative screening thresholds. The modelling directly evaluates the central hypothesis using either a binary threshold or continuous measure of severity or risk. As such, models do not evaluate what paramedics might infer from elevated values below the screening threshold, or how best to communicate this risk. As with all modelling, the results are based on a relatively small sample size and may not generalize well to alternative contexts, meaning that alternative approaches accounting for a wider range of behaviours and contexts may well yield more general insight.

1.12 10. Future Trends in Paramedic Practice

The 12-month period from publication of the last papers in this thematic series in 2020, to submission of the current issue in July 2021, has been mired by the COVID-19 pandemic. Over a number of months, the spotlight has turned on systems for prevention, early detection and control of communicable diseases. This is likely to have an enduring impact upon healthcare systems and paramedic services globally. Paramedics are frontline providers of emergency response in community settings in developed and developing countries. This is a unique role requiring a complex blend of clinical, logistical and interpersonal expertise. The COVID-19 pandemic has affected the settings in which many paramedics operate and may well have changed the public expectation of these services (Koivulahti et al., 2020). The COVID-19 pandemic has forced critical reflection on the role of paramedic services in shaping community health for improved health outcomes.

Ongoing pandemic-related change is likely to include a greater emphasis upon continuing education offerings developing self-narratives of paramedics re-evaluating their roles in community health. Community paramedic roles may expand as demand for at-home health care grows, with e-health delivery becoming commonplace. Recognising individual and communities' differing preferences for care pathways, paramedicine may better accommodate endpoint choice via engagement with vulnerable populations (Perry et al., 2018). The impact of the COVID-19 pandemic on community health inequities is undoubtedly still being felt, the lessons learnt and narratives from paramedics provide a strong basis to act upon these changes and challenges. Further studies focusing on emergency medical services in developed and other countries are important in order to gain a comprehensive overview of the future of paramedic practice.

10.1. Technological Innovations

The importance of pre-hospital blood testing in the hyper-acute and time-dependent care of patients remains undisputed among emergency physicians and service leaders. Pre-hospital laboratory tests pave the way for immediate patient care stratification, treatment initiation, therapeutic evaluation, and early hospital triage with the potential to reduce morbidity and mortality (Prottengeier et al., 2017). To ensure the proper evaluation of pre-hospital blood samples in clinical trials, it is imperative to understand their pre-analytical stability. Three parameters of a new point-of-care blood gas analyzer for the analysis of blood, basic metabolism parameters, and blood lactate in a pre-hospital setting under real emergency conditions are studied in this prospective interventional trial. Pre-hospital care time periods and results will be evaluated in a statistical analysis with respect to a clinically relevant cut-off value of up to 30 min pre-analytical blood sample stasis. The disease demonstrates the need and importance of an innovative point-of-care approach aimed at the early detection of sepsis already in the pre-hospital setting and the initiation of immediate therapy with antibiotics and fluid resuscitation at the doorstep.

The aim of the presented study is solely to investigate the pre-analytical stability of blood samples taken in the pre-hospital setting under realistic emergency conditions. To date, there is no such study in a pre-hospital setting. The Ethics Committee at the University of Erlangen-Nuremberg approved the study. All participating study physicians signed a declaration of participation. With

the completed study, reports and results will be shared anonymously and without restriction. An interim analysis is already planned in case of delayed evaluation. Unblinded data will be provided to the study group for publication purposes. The study is part of an application for financial support by the German Research Foundation in Erlangen and was registered at German Clinical Trial Register (C. Sheridan et al., 2020).

10.2. Training and Education Enhancements

Initial training sessions can provide knowledge on structured decision-making models and decision aids to paramedics. The goal is to deepen paramedics' knowledge on structured decision-making models, decision aids, difficulties with prior use, and opportunities for more use. Individual structured decision-making models and decision aids that can improve paramedic decision-making will be discussed. This training will provide a better understanding of the structured decision-making process. In the closing session, the knowledge gained on the topics will be discussed. Prior to the training, a questionnaire will be used to gather quantitative data about knowledge on structured decision-making, decision aids, prior encounters with decision aids, difficulties associated with their use, and personal opinions that may hinder their use, with opportunities for elaboration on open questions. The same questionnaire will be posted again after the training, along with another questionnaire focused on evaluation of the training. This quantitative data will be processed anonymously and reported in general without reference to individual paramedics.

Preparation for the training is essential. Observing decision aid and structured decision-making model use in practice allows for improvements to be made to the presentation in the training sessions to better tailor it to the specific group of participants. Question and answer sessions after each presentation allow for embedded education so that knowledge before and after the training can be identified per topic and per paramedic. Structured decision-making can first be introduced before decision aids, since models like FOR-DEC completely outline the structured decision-making process. Printed visual aids and a takeaway document can be provided to assist with remembering what was presented. Discussion with colleagues is essential for facilitating their implementation within the organization. Insights gathered from group meetings can provide suggestions for improvement; a strategy for the roll-out process can be elaborated based on examples set by other 'champions' after training is concluded. (Häske et al., 2019)

1.13 11. Limitations of Lab Results in Paramedic Decision-Making

Promoting laboratory testing by paramedics in out-of-hospital emergency medicine along with the results being more integrated into paramedic decision-making pathways represent a promising perspective. However, there are limitations related to laboratory results and the role of paramedics in lab requests. First of all, any laboratory result can only contribute to a decision-making process if a clear clinical question is being addressed (Sergi, 2018). While measuring parameters that are central to the criticality of the suspected medical condition is often a reliable approach, this can also mislead to medical errors.

In any medical diagnostic process, there exists the possibility of errors in pathology and laboratory medicine. If the requested laboratory parameters are being measured correctly and if the medical interpretation of the results are conducted according to the quality standards of the laboratory, false

positive and false negative findings can still occur. A common example includes the relatively high percentage of negative troponin tests in myocardial infarction cases. Such critical values can nevertheless lead to mistake decisions with great clinical consequences.

Critical values may also come from interference factors in laboratory medicine (Prottengeier et al., 2017). The existence of critical results highly depends on the physical and chemical components of the blood sample and their interaction. As the sample transit time is prolonged, various effects such as hemolysis and coagulation occur. Widespread new methods of sampling such as micro-sampling are not exempt from these interferences either. Such critical values can be either laboratory-based related to the individual and the conditions under which a laboratory process is performed.

11.1. Potential for Misinterpretation

Verify whether the data collection devices are working properly by referring to the reference data records. Recheck whether the laboratory data input is correct and whether preprocessing can be changed depending on the situation. Consider the time and place for which the laboratory data are processed as well as working for acute decision-making. It is also necessary to confirm whether the equipment is properly operated and whether incidental data cannot be obtained (Prottengeier et al., 2017). Inspect how much blood and what kind of information has been taken and how they relate to a disease suspected of a disorder. If laboratory data that recently existed are altered, resulting in a difference in clinical diagnosis, the reliability and credibility will be also evaluated. However, this does not mean that the experienced authority will result in positive influence only because it is firmly established adherence to rules and routines, whereas this often confirms a biased viewpoint. The threshold for a lab error detection depends on where the lab data is addressed. Thus, for PM, which will have limited clinical laboratory expertise, laboratory results may be taken for granted because they passed quality control and proficient personnel levels.

11.2. Situational Limitations

Although new technology and triage information can increase clinical data given to the consulting physician, paramedics are often still faced with a temporary loss of situational awareness and pieces of incomplete information. Lab results may contribute to feedback loops that widen the situational awareness gap. Furthermore, paramedics cannot infer a proper interpretation of lab values taken outside the emergency department (ED) setting. Care pathways including lab tests acquired neither in-hospital nor on-site require more than classical feedback. Before carefully developed dedicated solutions can be provided, improvement in the current process of communicating lab results must be targeted first.

Paramedics have a more advanced level of medical training now than in the past. However, there are still remarkable differences between on-site capabilities of paramedic systems worldwide. Bringing elevated patient levels to life support, i. e., through drug manipulations and invasive maneuvers, still results in differing circumstances for paramedics. Some countries restrict paramedics in actions like providing opiates or contact with defibrillating equipment, restricting these capabilities to emergency medical technicians (EMTs). Often, no or only very basic records of these events would be kept. Systems with advanced delivery of first-level treatment, such as

stop-and-think reviews, cascade dispatch systems, and fighting fires, thus would offer a greater capability of attaining a better understanding of the state of affairs regarding an attended case. Hence, the future development of an advanced parameter setting for dedicated on-site lab tests needs to vary internationally.

If local systems acquire lab tests in numerous ways, with parallel developments, the consulting personnel may be faced with an overwhelming onslaught of information from diverse sources, and yet miss the point on what is relevant supported by lab tests. Owing to in-house processing arrangements, interpretation on lab level can depend on non-standardized configurations, leading to a potentially different understanding regarding a state of affairs, also beyond the intended focus of clinical lab values in multi-organ failure (Prottengeier et al., 2017).

1.14 12. Research Gaps and Future Directions

While this study focused on examining the medical lab results available to paramedics in the local City of Kitchener, where they are frequently required to work with acute patients, there are some avenues for potential future research. For example, investigating whether the same lab results are employed in other districts/settings within Ontario. Previous work suggests that while there are commonalities, there are also variances between local regions with regards to lab results available to paramedics. Research is warranted to ensure best practices throughout Ontario.

For further investigation, the perceptions of paramedics could also be explored. While study participants were extremely positive about having medical lab results available, it would be worthwhile to determine whether results not available would impact decision-making. Expanding the qualitative research in this field to larger studies would produce valuable data about the way paramedics make decisions upon encountering lab results. Future research that addresses the limitations of the study could produce research that is more generalizable to a broader audience, rather than simply Kitchener. Specific recommendations for further studies can be found in the section below.

As discussed previously, a similar study focusing exclusively on the primary care laboratory results data as currently available could provide deeper insights into its use by paramedics. Similar to the current study's exploration with local paramedic services, such a study could also explore the current accessibility and integration of results from other laboratories within the province with paramedic services. This would provide greater insight into the factors that may affect inclusion/exclusion at the provincial level and decision-making at the inter-facility transfer level.

Because acute staff interactions can be at both public and private hospitals in Kitchener and Guelph services with varying levels of lab results integration, further explorations of how those interactions occur and how lab results may affect decision-making would be another worthy avenue for future research. Since these may not include Emergency Services information systems, a different form of cooperation/communication is required from the paramedic's standpoint, as may also be the case when interacting with district schools and group homes. Such future research would ideally accompany a framework to ensure continued and expanded field collaboration with Emergency Services and medical establishments in research initiatives. Reflections from the paramedic services' Chief on the relationship with the medical community and how best to

continue it could be especially valuable to understanding the specific factors that might impede or promote future collaboration. Emphasizing areas where cooperation took place successfully might be particularly worthy of further examination.

12.1. Need for Further Studies

Despite the advances in decision-support systems, laboratory results, in the form of simple analytical value lists, still compose a part of the current clinical decision-making structures. Examination results provided for treatment are complicated in terms of the decision processes generated around them when used, i.e. during preliminary diagnostics and the planning and implementation of treatment. In the case studies, every laboratory examination measured and its results used by paramedics present a crucial question answering component included in sequences to first orders. In these cases, laboratory results directed paramedic decisions by either excluding or affirming the suspected conditions. This is a big finding since previous work has not worked through how paramedic interpretation of analytical results in terms of illness recognition and therapeutic reasoning is accomplished. To afford paramedic decision-making on a laboratory result list, multimodal resources in terms of knowledge resources and conversational resources are orientally used. The former mainly analyses illness classification and therapeutic domains. Thus, knowledge resources are detected as affording or constraining interpretation on a laboratory result list. The latter focuses on resources in the sequential context, e.g. turn design, sequential placement and tone of voice. Contemporary studies have approached hospital laboratory results to some extent (Koivulahti et al., 2020), but neither paramedic decision-making on laboratory results nor laboratory results as part of decision processes have been investigated. There is a need for further studies worldwide.

Certain analytical results could be subject to further scrutiny. In particular, in Clinical Example: Arterial Blood Gas Results, when clinical prediction shortcuts constitute suspicion and ground recommendation operator actions, also the forces of social circumstance and knowledge could be subject to closer scrutiny. This could afford an understanding of the joint work between ABG results and clinical knowledge in the construction of paramedics' treatment actions. In adding to that, the ABG result list presented contains components on which detection can be said to work across courses of action, dealing with different modalities and cognitive environments. The compatibility checker speaking gives permissions for the rest of the list before being fully presented. In this case, it would be fruitful to uncover how these multimodal resources afford the construction of paramedic actions in unison. There would be a need to further study how these developments translate into knowledge used in paramedic education, training, and the broader societal context where they act.

12.2. Potential Research Areas

The role of laboratory results in paramedics' decision making with a focus on acute situations has been studied to some degree (Koivulahti et al., 2020). Various acute situations where laboratory test results may drive paramedics' decisions need to be specified in more detail. For example, it would be of interest to examine the pre-hospital use of the point-of-care tests mentioned earlier from various perspectives. An examination of both the possibilities and challenges with regard to

the use of this technology would be fruitful. There is also the possibility to examine more specific acute situations e.g., hyperglycemia and acute cardiac symptoms.

In addition to focusing on acute situations and specific laboratory results used, literature concerning paramedics use of laboratory results to make decisions is non-existent, particularly in Europe. Thus, the development of knowledge in this area through original studies is needed. It would be highly interesting to analyse how laboratory results are used in various situations when modifying prehospital treatment or care. In light of no previous research, it would be interesting but challenging to conduct the analysis in a broader manner. However, using a specific situation would help to acquire data needed for the study.

The possibility of patients sending their own laboratory test results could be examined from various perspectives. On the one hand, examining the paramedics' view on and thoughts about this would be important, and on the other hand, studying patients themselves could yield thought-provoking results in terms of their self-management. It would be interesting to ask patients if they even believe that they would get a response from their own laboratory test results, or what do or would they expect from this service. Would this make people frightened and lead to a more or less urgent 9-1-1 call than before? The challenge with this type of study is to make sure there will be a diverse set of patients participating in it.

Research would be highly needed on the coding scheme where laboratory results are classified as useful, not useful/harmful, and so forth. How does a result fall under a category, and does it stay in the same one in various situations and courses of action? It would be important to study this from various perspectives. Standardization of coding would improve understanding of the decisions made based on laboratory results.

The influence of the unique local context should be paid attention to in more detail, including in some cases direct contact with local paramedics in a specific setting. This would open up a completely new aspect to the research.

1.15 13. Conclusion

The goal of paramedics after arriving on the scene is to assess the patient's condition and provide treatment if necessary or transport them to a definitive care facility if not. When assessing patients suffering from acute illness or injury, this is usually accomplished using a systematic approach such as the primary or secondary surveys. Having a preconceived idea of the core issue, or a preliminary diagnosis, is essential for this assessment. A preliminary diagnosis assists in guiding care and gauging how urgent transport might be. Additionally, it also allows paramedics to provide the receiving facility with advanced warning before arrival using a field report. In practice, this means dispatching a location ID or circumstance indication followed by the "signs and symptoms", which denotes the problems expected to be encountered on-site. A preliminary diagnosis is key when determining which receiving facilities are appropriate. In particular, some conditions like STEMI and stroke have treatment windows of several hours, so early intervention is critical.

Despite the importance of preliminary diagnoses, they are often difficult when time is critical. However, when lab results are received, interpretations of those results can rarely be viewed as misinterpretations. Using lab results, paramedics can answer the three key questions faster than

they can arrive on-site with their vehicles: (1) Are these lab results normal? (2) Does anything suggest reason for concern? (3) If so, what is this condition?). Lab results can direct paramedic decisions just like symptoms can, but with a greater degree of certainty. Thus, they provide a tremendous asset in guiding decisions in the face of uncertainty. While the literature does not comment on specifically how lab results are handled once received, reviews of the state of the art of prehospital medicine classify the handwriting of continuous ECG transmissions and the field interpretation of them to be within the scope of practice of paramedics. Thus, it stands to reason that the handling of lab results would be within scope as well.

Understanding how lab results guide decision-making is crucial to better understand and address the design implications for lab result displays. A review of 20 existing lab result displays showed them to nearly uniformly contain a table showing a list of all electrolytes or other conditions measured, their values, interpretations, and any limits. As these tables contain a wealth of information, distilling this information is key. However, the ability to quantify things like deviation with a signal strength has been found to be more helpful than the tabulated values or the presence of indicators for a hidden index with each item, suggesting that more information may be better than less (Koivulahti et al., 2020).

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