Incorporating Clinical Decisions into Standardised Caremaps

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***Abstract*— Caremaps are a visual representation of the care process that can help clinicians make quick and accurate decisions. However, contemporary caremaps lack a systematic, easy-to-use graphical representation method for care decision points (DPs), which are often missing. This paper addresses this gap by presenting a consistent model and representational notation that easily alerts those using caremaps when a clinical decision must be made. Through analysis of clinical decisions and identification of those that directly impact the path of patient care in the contemporary caremap, this paper extends the well-known formalism of the activity diagram for caremaps. This results in the *extended TaSC* (*e-TaSC*) model and notation, which allows caremaps to be modelled allowing systematic visual representation of clinical DPs. The e-TaSC model is evaluated in two case studies: gestational diabetes mellitus and trauma caremaps. In both case studies, e-TaSC enabled systematic consideration and inclusion of clinical DPs at appropriate locations leading to clearer, easier-to-follow and more comprehensive caremaps than found in the literature.**

Keywords—caremaps, clinical decisions, decision points

I. INTRODUCTION

For as long as modern medicine has been practiced, clinicians have sought visualisation approaches, including graphical ones, for making quick, accurate and confident clinical decisions [1-4]. However, a 2011 report by the US Institute of Medicine (IoM) described information visualisation in clinical medicine as underdeveloped when compared and contrasted with other scientific disciplines [5]. Attaining visualisation by graphically modelling [6, 7] the process of patient care for a given medical condition or hospitalisation event is not new as a variety of presentation styles have been used, including: *Unified Modelling Language* (UML) process modelling to represent the ongoing clinical management of a chronic condition [8]; *Business Process Modelling and Notation* (BPMN) to visually map the treatment flow encapsulated in clinical pathways [9]; and, *Influence Diagrams* to model the structure of complex clinical problems, identifying decisions to be made, the sequence in which those decisions may arise, the information available to make the decision and the probability of uncertain events [10]. Caremaps present the patient care process and have, over time, adopted elements from some of these visual representation styles [11] but have generally lacked standardisation and particularly lacked comprehensive representation of all types of necessary clinical Decision Points (DPs) within them.

This paper is part of ongoing work in which the authors have presented TaSC [12], a model for standardising the development and presentation of clinical caremaps. TaSC is an acronym for: *Towards a Standard for Caremaps.* Caremaps consist of: (i) an entry point; (ii) activity nodes that represent clinical tests, observations or interventions to be performed; (ii) arcs that indicate the sequence of care activities; and (iii) an end point at which the patient exits the caremap. The standard in TaSC for nodes within the caremap is that they represent activities conducted in the performance of patient care. However, nodes are often observed to also represent within their scope one or more *latent clinical decisions* with criteria that identify which divergent path ongoing patient care should take. Clinicians may consider such a decision point as part of selecting the treatment path for the individual patient. In much of the literature caremaps incorporate latent DPs, and lack a standardised approach to identifying and representing them [12]. This paper explores this gap by investigating an extension to TaSC for identifying and representing DPs with decision criteria

II. RELATED WORK

The clinical decision-making landscape is becoming increasing complex [13, 14]. Patient care involves making complex clinical decisions to determine the next care [15]. Accurate, personalised information enables clinicians to provide precision, rather than just population-based medicine [16, 17]. Medical decision-making is often performed under conditions of uncertainty within a complex *decision threshold model* [18, 19]. The *diagnostic threshold* assists the clinician to estimate the probability that the patient has the disease, and evaluate whether further tests are required [19]. The *treatment threshold* is the point where the probability of disease or its consequences is such that treatment is considered beneficial [18, 19]. This threshold *model* in caremaps is often represented similar to the *if-then-else* rules or statements and *multiple cases of condition-action* statements similar to the *case-switch* statement common to software programming languages. All outcome options within the decision threshold model of a caremap must be represented within the graphical visualisation model. However, Caremaps like that shown in Figure 4 of Panzarasa et al [20] provide the clinician with a graphical cue representing where a clinical decision needs to be made, while failing to provide the justification or necessary criteria that would assist them to easily identify the best path for their patient. Others, like those shown in Figure 1 of Milne et al [21] and Figure 1 of Saint-Jacques et al [22] present quite granular justification for the threshold values or criteria to be considered when making clinical decisions. However, they lack any visual cue for easy identification or differentiation of DPs from standard activity nodes. Examples are found in Milne et al [21], McClure et al [23] and Saint-Jacques et al [22]. This paper contends that integrating DPs into the TaSC caremap model is a combination of: (1) a visual cue for clinicians to easily identify when a clinical decision needs to be made; and (2) an easy way to identify criteria that enables easy selection of the appropriate treatment path based on the accumulated evidence-based knowledge regarding the current patient.

III. Clinical Decisions

There are many clinical decisions that might inhabit a particular caremap node. For example, a treatment activity may require the clinician to consider whether an aseptic technique is required, which dressing to use or the selection of a clinical resource to assist during treatment. These decisions do not impact directly on the flow of care i.e. the pathway the patient takes within a caremap. In identifying DPs to be included in a caremap we are only concerned with those decisions that have an impact on the path taken by the patient: DPs that are critical to patient flow.

Clinical decisions that may give rise to DPs in a caremap result from six aspects of clinical work identified by Richardson et al [24] as follows:

Clinical Evidence: The identification and selection of clinical evidence from clinical trials and clinical practice guidelines for use in the creation of tools, like caremaps, requires decisions regarding how to gather the right clinical findings properly and interpret them soundly.

Diagnosis: During diagnosis decisions are made regarding the selection and interpretation of diagnostic tests.

Prognosis: Prognosis requires decisions of how to anticipate a given patient's likely course.

Therapy: Therapy decisions consider how to select treatments that do more good than harm.

Prevention: Screening and reducing a patient's risk for disease are prevention decisions.

Education: Consideration of how to teach the clinician, patient or patient's family what is needed fall within the remit of education decisions.

IV. The E-TaSC Model

Previously, we addressed the lack of a standard for caremap structure, content and development process. McLachlan et al [12] proposed what is described as TaSC. The extended TaSC model, presented in this paper, is termed *e-TaSC*.

Structure: Caremaps with DPs are presented as flow diagrams. Figure 1 presents the e-TaSC *unified modelling language* (UML) class model that identifies the entities and relationships among the entities making up the structural elements of a caremap with DPs. All structural elements and their notation are presented in Table 1. The elements are inspired by the standardised pictorial elements normally observed in UML and hard state chart notations. The additional elements related to e-TaSC are shaded in grey. Following e-TaSC, the standardised structural model of the caremap with DPs is demonstrated in the content model shown in Figure 2.

Content: Similar to TaSC, three main content types are captured in e-TaSC; diagnosis, treatment, and management/monitoring. As shown in Table 2, these broad content types are related to a set of specific medical activities and decisions, which are shaded in grey. Each content type represents a different caremap level, while the activities and decisions are components of the caremap.

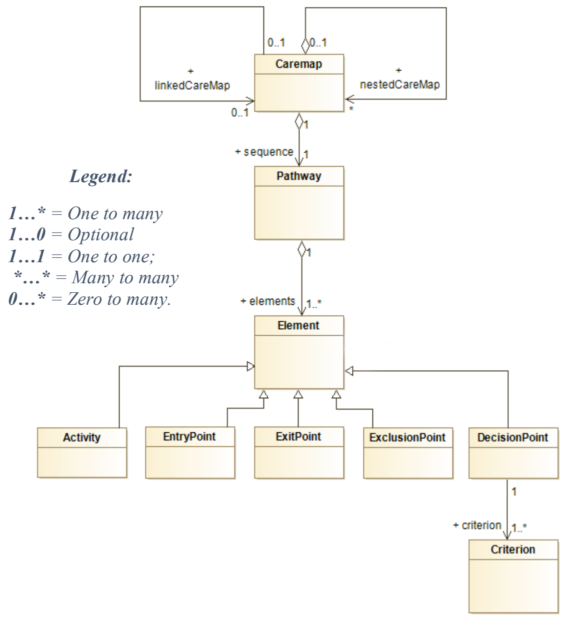
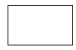
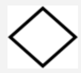
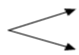
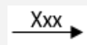


Fig. 1. The e-TaSC entity relationship model for the caremap with clinical decisions

Development: There are two types of clinical decision making: (i) unconscious, fast, intuitive decision making; and, (ii) deliberate analytical decision making. Sound clinical decision making involves a combination of the two, informed by clinical expertise and tempered to minimise cognitive and affective biases [25, 2]. Generally, a limited amount of information is required to reach a sufficiently satisfactory decision: a process described as satisficing [25, 26].

The DPs identified for inclusion in a caremap resulted from one of three activities where: (1) a divergence was seen in the path of a caremap - i.e. where two or more paths were already being represented as possible outcomes from an

TABLE I. THE E-TASC CONTENT TYPE, ACTIVITIES AND DECISIONS

	Element	Description	Notation
1	*Entry point*	Beginning of the caremap	
2	*Exit point*	End of the caremap	
3	*Exclusion point*	Exclusion from the caremap, as the patient does not belong to the targeted population	
4	*Activity*	A care or medical intervention that is associated with a medical content type *(see Table X in next section)*	
5	*Nested Activity*	An activity that has an underlying caremap	
6	*Decision*	A cognitive process of selecting a course of action that is associated with a medical content type *(see Table X in next section)*	
7	*Nested Decision*	A decision that has an underlying caremap	
8	*Flow*	Transition from one activity to another along the pathway	
9	*Multiple pathways*	Flow from an antecedent activity to a number of successors from which a decision point arises	
10	*Decision Criterion*	Conditional values used to identify the path to be taken based on the clinical decision being made	
11	*Nested caremap connection*	Connection between an activity and its nested caremap	
12	*Multi-level caremap connection*	Connection between a series of linked caremaps	

activity node; (2) the clinical practice guideline (CPG) identified a scale or set of diagnostic thresholds for use in deciding whether or which treatment a patient should receive; or (3) where the expert clinicians we consulted identified availability of two or more treatments for a given test result, symptomology or diagnostic activity.

TABLE II: CAREMAP CONTENT TYPE, ACTIVITIES AND DECISIONS

Content Type	Activity *(associated with Content Type)*	Decision *(associated with Content Type)*
Diagnosis	Review patient's medical history	Is there a suspicion of the targeted disease?
	Collect patient history	
	Ask personal, lifestyle questions	
	Clinical examination	
	Diagnostic Test	Has the initial suspicion been confirmed?
	Disease assessment	
Treatment	Set goals	Is the considered treatment going to be beneficial?
	Consider different interventions	
	Assess likely harm to benefit ratio	
	Treatment Decision	
Monitoring	Review patient records	Have the goals been achieved? Is there a need to change the current treatment?
	Clinical examination	
	Targeted examination	
	Evaluate goals	

V. CASE STUDIES

In this section we demonstrate application of e-TASC to case studies in gestational diabetes mellitus (GDM) and helicopter emergency medical service (HEMS) trauma care. Both are quantitatively evaluated, while the HEMS caremaps is also qualitatively evaluated.

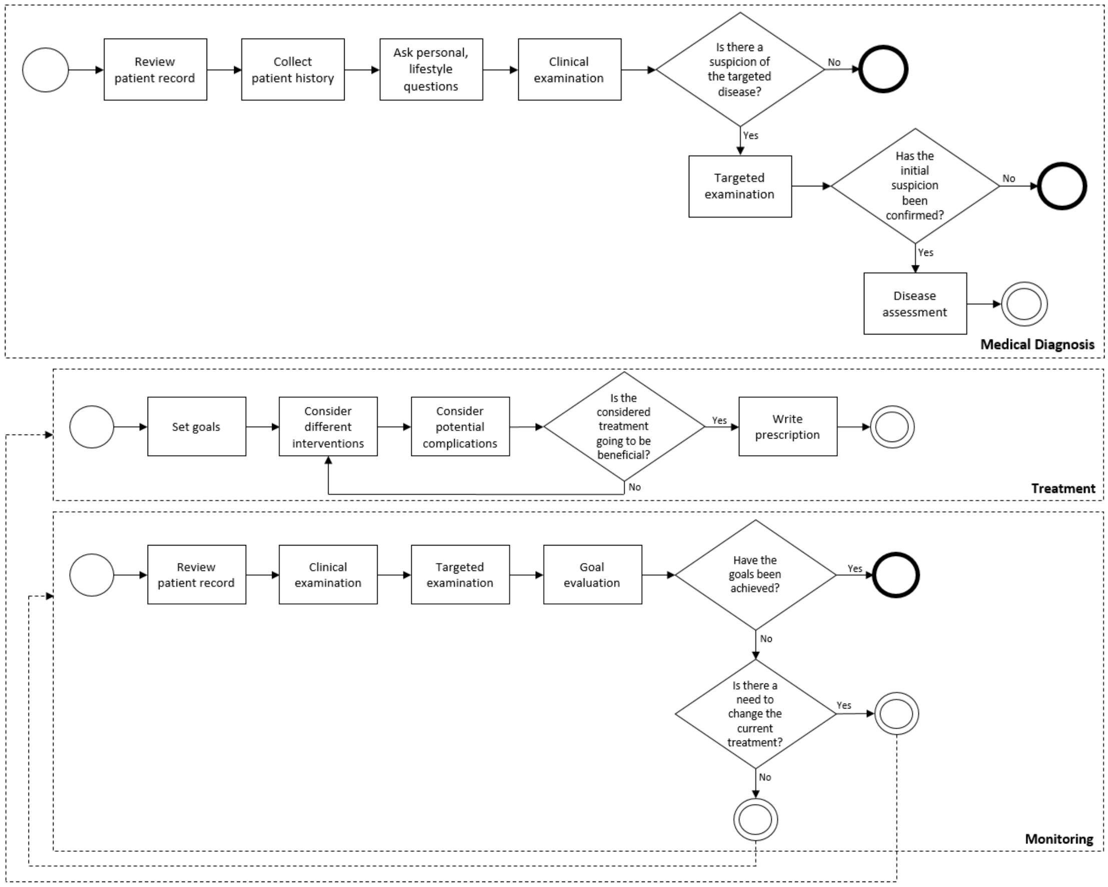


Fig. 2. The e-TaSC content model for the Caremap with decisions

A. Case Study 1: GDM Caremap

As part of PAMBAYESIAN [27] we are creating a Bayesian Network (BN) model [28] to predict treatment needs for individual mothers with gestational diabetes mellitus (GDM). The process initially required three caremaps, for: (1) the midwifery booking visit; (2) GDM diagnosis; and, (3) clinical management of the patient's condition. Later, a fourth sequela caremap was developed for postnatal assessment and prediction of the likelihood of: (a) the mother going on to develop Type 2 Diabetes (T2D) [29]; and, (b) the child going on to develop some form of diabetes [30, 31].

GDM occurs in 2-25% of pregnancies [32, 33] and, depending on the diagnostic criteria used, rates across the United Kingdom (UK) may be as high as 17% [34, 33]. While the original definition for GDM was based on maternal risk for developing diabetes postpartum, newer glucose criteria have been developed based on risk of maternal and neonatal complications [35, 36]. While a number of international standards provide diagnostic thresholds for GDM, in 2015 the National Institute for Health and Care Excellence (NICE) published an updated guidance for diabetes in pregnancy [37]. The Barts Health Trust (BHT) CPG used in development of the GDM caremaps was based on this 2015 NICE guideline.

Inputs: Inputs for the gestational diabetes caremaps were: (a) a clinical practice guideline from Barts Health NHS Trust in East London that is currently in use for the care of women with diabetes in pregnancy; and, (b) clinical expertise and consensus from midwives and diabetologists from the same NHS Trust. An AGREE II study was conducted [38] to evaluate the adequacy and appropriateness of the Barts Health CPG that was used in the development of the GDM caremaps.

Development: An iterative development process was used wherein the health informatician, decision scientist and midwifery fellow all worked together to deliver an initial version of the caremap based on CPG and clinical expertise. The initial caremap was revised and refined during sessions with the midwives and clinicians. As an early example of the output of this process, Figure 3 presents the clinical Management Decisions caremaps for GDM, both (a) with and (b) without DPs. It can be seen from this example that the addition of DPs provides richer contextualisation for selection or justification of the various treatment paths that may be undertaken in the care and management of a patient with a specific condition.

Validation: Validation was performed through consultation seeking consensus from three participating diabetologists with tertiary care experience treating obstetric patients under the CPGs used in the development of the caremaps.

B. Case Study 2: HEMS Caremaps

The Helicopter Emergency Medical Service (HEMS) is a physician-led and well-established component of trauma systems in every western, and most high-income countries [39, 40]. Helicopters are capable of transporting the major trauma patient significantly faster than ground-based services, and while costly, this mode of transport is seen to have a significant impact on reducing mortality [41-43]. HEMS clinicians have a history of seeking algorithms to make critical life-and-death medical decisions in trauma care situations:

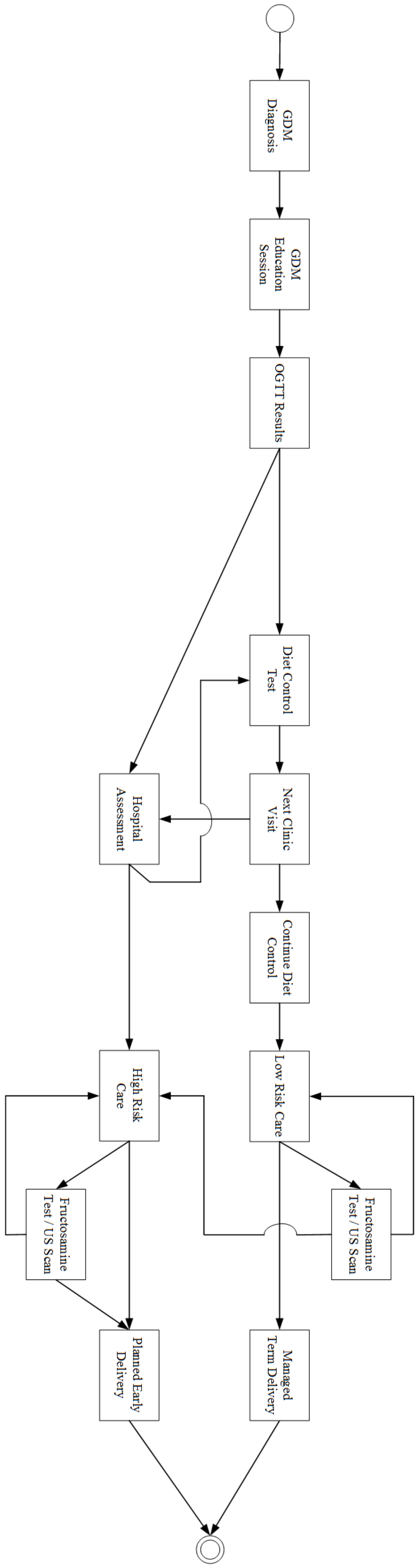


Fig. 3a. Caremap for GDM without DPs

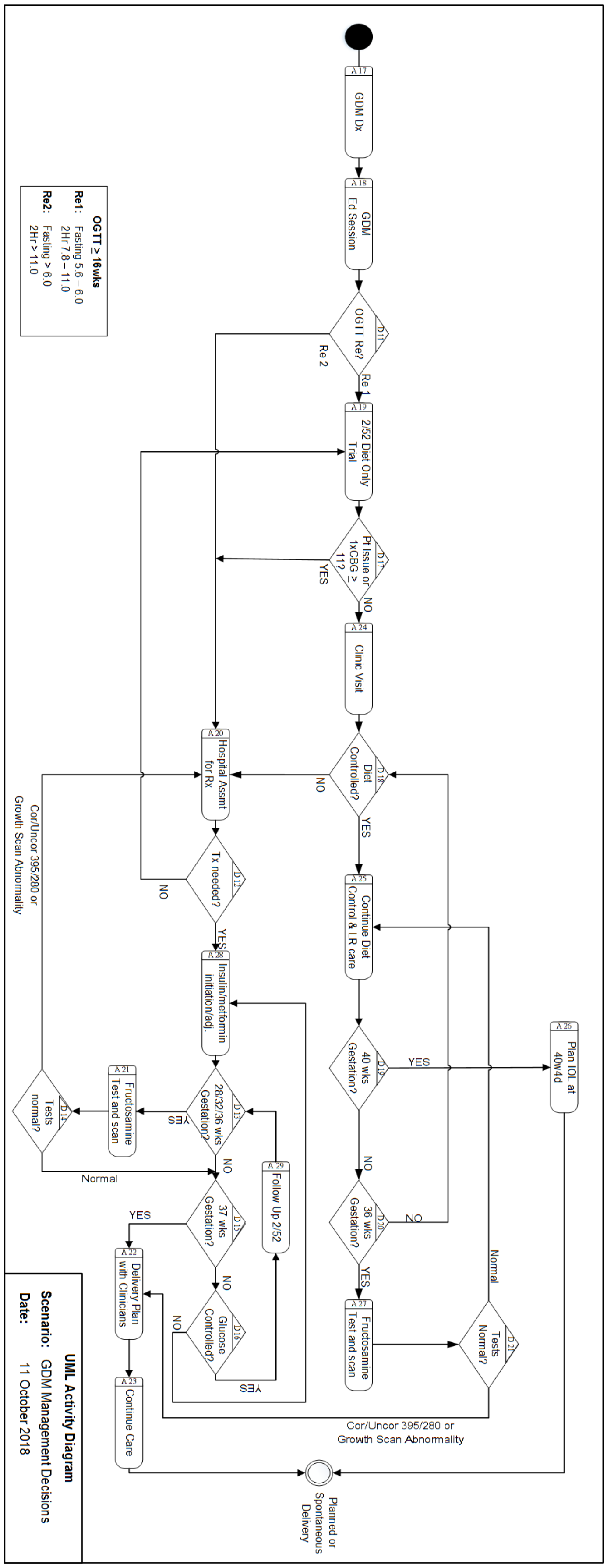


Fig. 3b. Caremap for GDM with DPs

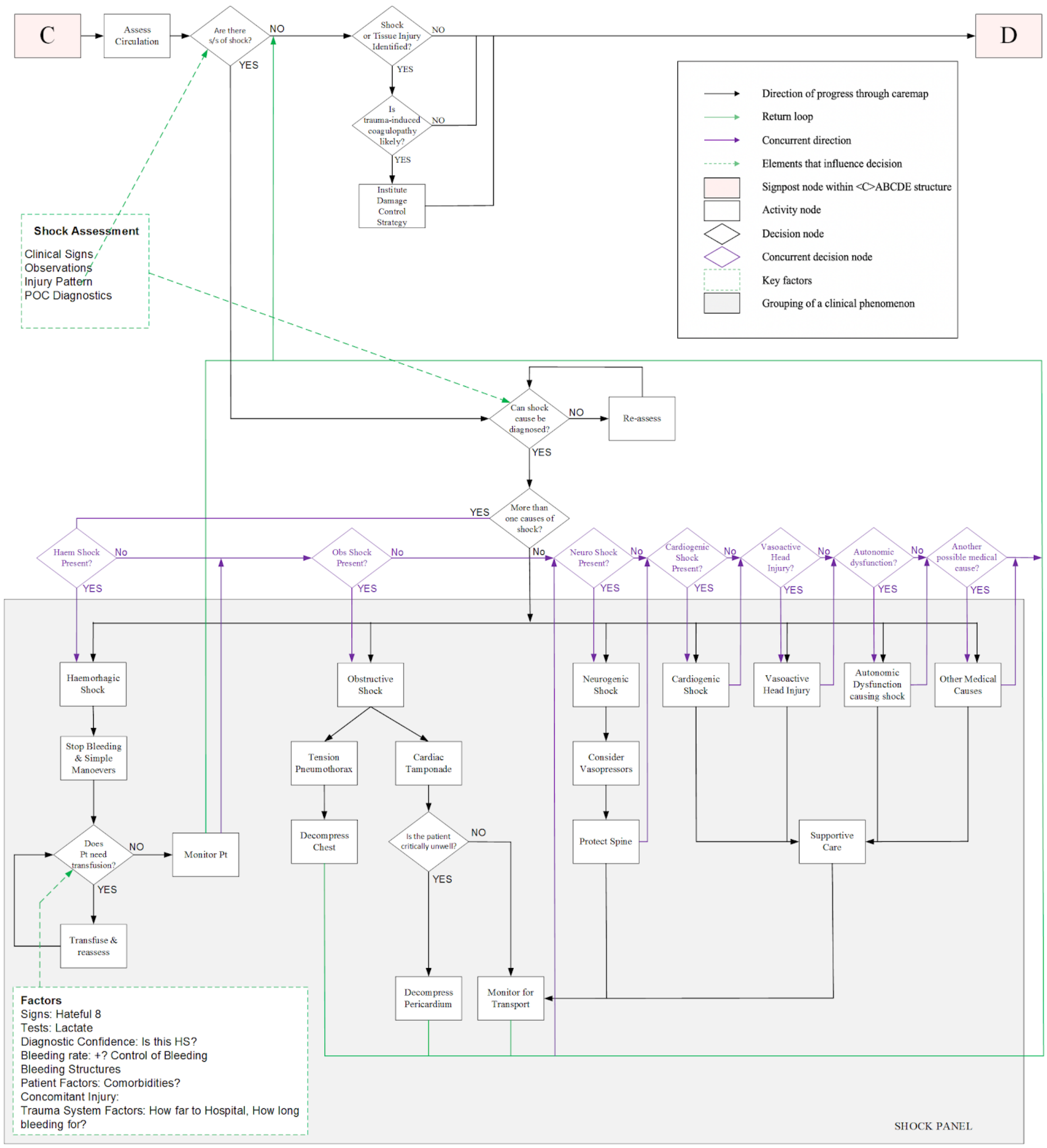


Fig. 4. Extract from the <C>ABCDE Caremap

whether simple counting tools for calculating treatment based on observable symptoms or patient responses, or a complicated CDSS built on medical AI or Bayesian Networks [44, 45]. HEMS crews are literally at the bleeding edge of critical care practice, and as a result, are often on the forefront of any new research that could make an appreciable difference in outcomes for their patients.

When HEMS clinicians arrive on-scene a range of triage and treatment processes developed during the last several decades and refined into an ever-growing collection of mnemonic terms are engaged. Mnemonics are a memory-aid learning strategy: catchy phrases to prompt recall of a process or subject [46]. Over the years simple mnemonics like ABC, which stands for airway, breathing and circulation [47], have been extended and enhanced by a variety of first responder and trauma care organisations. St John Ambulance first responder manuals added danger and response to create DRABC [48]. Military medics recognising the need to prioritise bleeding in their patient cohort added a prefix for catastrophic haemorrhage [49], and later appended disability and exposure, resulting in the more comprehensive <C>ABCDE [50]. Given that any effort to sequence prehospital care must faithfully report the activities of clinicians, and those activities are guided directly by these mnemonics, this case study set out to develop caremaps based on a number of pre-hospital care mnemonics.

Inputs: Inputs for the trauma care maps included: (a) a clinical reference textbook prescribed for pre-hospital emergency medical training [47]; (b) clinical practice guidelines issued by national or collegiate health authorities and intended for use by doctors, paramedics and ambulance personnel (including: www.jrcalc.org.uk); (c) current literature on prehospital emergency care; and, (d) clinical expertise from a team of pre-hospital clinicians, paramedics and trauma fellows.

Development: The trauma fellow was consulted to elicit current pre-hospital care plans to be targeted, which were resolved from his ongoing survey and interviews with pre-hospital emergency care clinicians. This process resolved two primary targets: (i) SCREAMER – Scene survey, Communicate, Read the scene, Everyone accounted for, Assess patients, Method of extraction, Evacuation route and Right facility; and, (ii) <C>ABCDE – Catastrophic haemorrhage, Airway, Breathing, Circulation, Disability and Environment and Exposure. From literature and his survey, these were evaluated as those most common to current HEMS practice. Literature describing SCREAMER was identified [47], and as had been the opinion of several clinicians during the interviews discussed above, it was observed that terms used in SCREAMER were influenced by its authors experiences attending motor vehicle accidents. On the suggestion of our clinical experts, the SCREAMER caremap uses adapted language to generalise application to a wider range of prehospital emergency scenarios. The same textbook [47], along with other clinical literature [51, 52] described the <C>ABCDE primary survey approach. An initial overview caremap was created for each, and was refined during short consultations with clinicians. An extract from the <C>ABCDE caremap showing activities and DPs for the circulation and Shock Panel is provided in Figure 4.

The complete SCREAMER caremap can be viewed at:

http://www.mclachlandigital.com/screamer.png

The complete <C>ABCDE caremap can be viewed at:

http://www.mclachlandigital.com/cabcde.png

Validation: Initial review and validation was conducted with the clinicians. Once there was consensus between them, extended validation was performed by reviews from a small group of pre-hospital emergency care clinicians who had been interviewed prior to the caremaps creation. Some minor modifications and 'fine tuning' was performed on the basis of these reviews that included the addition of clinical factors and symptomatology for a number of decision nodes, and the addition of a process loop for triaging and treatment in situations that presented with multiple casualties.

VI. Evaluation

Quantitative: One approach to evaluating the effect of standardisation on caremaps is the quantitative approach by which we assess both the time taken to develop and achieve consensus on each caremap, and the overall cost of development. Table 3 shows the number of individual caremaps or caremap segments produced by each case study.

TABLE III: QUANTITATIVE EVALUATION METRICS

Case Study	Clinicians	Iterations	Total Caremaps
1	2	3	3
2	3	9	12

The initial caremap standard, TaSC, was developed during the period between case studies 1 and 2. As TaSC was refined and increased in familiarity to those involved, and even as the standard was extended with DPs, the time taken to deliver each individual caremap significantly reduced. This increase in efficiency of caremap development is shown in Table 4.

Qualitative: Another approach to evaluating the extended e-TaSC approach is qualitative: to evaluate through responses to a convenience survey on the accuracy characteristics of the delivered caremaps with DPs. The mnemonic caremaps from the fourth case study were evaluated through the operation of a survey instrument using a forced-choice Likert scale. The survey questions posed to clinicians are found in Table 5.

Survey participants were seven self-identifying experienced emergency and trauma clinicians including a HEMS doctor, paediatric emergency nurse prescribers (RN/SCN), Mobile Intensive Care Ambulance (MICA) paramedics and a HEMS-experienced midwife. In each case clinicians examined SCREAMER and <C>ABCDE trauma caremaps to evaluate whether they possessed qualities similar to the CPGs, mnemonic sequence and care processes. Results of the survey demonstrate that caremap structure and path, when examined independently, were considered to be accurate 88% (Q1) and 76% (Q2) respectively, while placement, purpose and criterion used to describe DPs were 86% (Q3) and 95% (Q4) accurate. Caremaps were assessed overall to be 93% accurate when all elements were examined jointly, and 95% (Q6) easier to use than clinical documentation they were based on. This survey of practicing clinicians indicates a high degree of accuracy for caremaps developed using the e-TaSC approach. While conclusions cannot be generalised due to the limited number of participants.

VII. Discussion

The e-TaSC approach is promising in its efficient and standardised production of caremaps with high clinical accuracy. An important benefit is that e-TaSC is generic: capable of application to any medical condition or clinical practice. Extending TaSC with DPs increases the caremap's utility, providing clinicians with a visual prompt for when significant clinical decisions must be made, as well as the evidence-based criteria to support selection of the appropriate treatment path for the current patient.

The e-TaSC caremap is as robust, applicable and accurate as the CPG, medical literature and expert guidance allows. Different local health districts develop their own CPGs with diagnostic and treatment thresholds customised for the local population. One issue for application is that even when the caremap with DPs is based on a national CPG and evidence-based literature, the aspect of local CPGs and clinical expertise may influence the caremap and DP criteria, that subsequently, limits the resulting caremap's applicability to a wider audience.

The major significance of e-TaSC is its visual simplicity and standard appearance. If the range of caremaps in use within a facility were to be standardised using e-TaSC, clinicians could engage with e-TaSC caremaps in clinical practice without the need for learning new presentation styles and notations as they move between different caremaps or units within the hospital. The presence of decision criteria acts as a simple CDSS, prompting the clinician with the path to be taken and next treatment activity to be undertaken. Furthermore, while still being entirely grounded in the CPG

TABLE IV: THE E-TASC CONTENT TYPE, ACTIVITIES AND DECISIONS

Case Study	Clinician Rate/ Hr (£)	Clinician Hrs	Clinician Total (£)	InfSci Rate/ Hr (£)	InfSci Hrs	InfSci Total (£)	Total (£)	Total per Caremap (£)	Hrs per Caremap
1	104	9	936.00	80	23	1840.00	2776.00	925.33	10.7
2	123	12	1476.00	80	25	2000.00	3476.00	289.66	3.1

TABLE V: QUESTIONNAIRE FOR EVALUATING TRAUMA CAREMAPS

Q	Survey Response Prompt (*After viewing the caremap…)*	Aspect Evaluated
1	I find that the caremap faithfully reproduces the necessary structure represented in the mnemonic.	Accuracy of caremap structure to mnemonic.
2	I find that the caremap path progression is similar to the path a clinician would take in applying the mnemonic during assessment and treatment of the trauma patient.	Accuracy of caremap path progression to actual treatment.
3	I find that the placement and purpose of decision points within the caremap are similar to the decisions a clinician would make during each stage of the caremap.	Accuracy of decision points in placement and purpose.
4	I find that the criterion associated with the paths away from each decision point are similar to the diagnostic and treatment thresholds and other criteria clinicians would expect to find in the CPG used in the caremap's development.	Accuracy of decision point criterion to the CPG.
5	I find that the caremap structure and path progression, and the placement and purpose and criterion for decision points when read together has neither conflicts nor inconsistencies as would be expected in the actual trauma patient treatment process.	Accuracy and realism for the entire caremap with decision points and hence for the entire clinical logic flow.
6	I find the caremap to be simpler and easier to use in practice than the CPGs and clinical literature its development was based on.	Accuracy of claim that the caremap has utility in clinical practice

and evidence-based medical literature they would need to refer to the CDSS. e-TaSC has the potential to expedite treatment, improve treatment consistency and save time for both the patient and clinician. All of which reduces healthcare cost and resource consumption and improves patient quality of life.

VIII. SUMMARY

There has been inconsistency in the way DPs are being modelled and incorporated into caremaps and diagrams despite the recognition that clinical decisions are essential components that must be visually represented. This paper presented the extended TaSC (e-TaSC) model that requires systematic consideration of DPs in a caremap that is being modelled. Through using e-TaSC to model the gestational diabetes mellitus management and HEMS trauma caremaps, which are clinically and technically challenging, evaluation was performed to establish that e-TaSC enables the systematic inclusion of the decision criteria in a manner that simply and easily enables selection of the treatment path to be taken for an individual patient. Future work will include development of easy-to-use web-based tools that can assist clinicians and information scientists to develop caremap models that could be formally specified in information interchange formats such as XML and JSON.

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