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# Development of Requirements Analysis Tool for Medical Autonomy in Long-Duration Space Exploration Missions

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***Abstract*—**Improving resources for medical autonomy of astronauts in prolonged space missions, such as a Mars mission, requires not only technology development, but also decision-making support systems. The Advanced Crew Medical System - Medical Condition Requirements study, funded by the Canadian Space Agency, aimed to create knowledge content and a scenario-based query capability to support medical autonomy of astronauts. The key objective of this study was to create a prototype tool for identifying medical infrastructure requirements in terms of medical knowledge, skills and materials. A multicriteria decision-making method was used to prioritize the highest risk medical events anticipated in a long-term space mission. Starting with those medical conditions, event sequence diagrams (ESDs) were created in the form of decision trees where the entry point is the diagnosis and the end points are the predicted outcomes (full recovery, partial recovery, or death/severe incapacitation). The ESD formalism was adapted to characterize and compare possible outcomes of medical conditions as a function of available medical knowledge, skills, and supplies in a given mission scenario. An extensive literature review was performed and summarized in a medical condition database. A PostgreSQL relational database was created to allow query-based evaluation of health outcome metrics with different medical infrastructure scenarios. Critical decision points, skill and medical supply requirements, and probable health outcomes were compared across chosen scenarios. The three medical conditions with the highest risk rank were acute coronary syndrome, sepsis, and stroke. Our efforts demonstrate the utility of this approach and provide insight into the effort required to develop appropriate content for the range of medical conditions that may arise.

***Keywords*—**Decision support system, event sequence diagram, exploration mission, medical autonomy, scenario-based queries, space medicine.

## I. Introduction

As manned long-duration deep space exploration missions are envisioned in the upcoming decades, the need to enhance medical autonomy has become a priority for the Canadian Space Agency (CSA) [1], [2]. Maintaining astronaut health throughout prolonged space travel is one of the biggest challenges in our exploration future. Technological tools such as satellites have already proved their capability to explore deep space, but humankind has not yet gone beyond the Moon. Substantial communication delays (e.g., between Mars and Earth), a higher risk of critical medical events, and limited resources are examples of challenges that will require efficient decision support systems to protect crew members' health and mission success [3]-[5]. Scientific and technological developments are needed to establish medical autonomy critical to extended missions. Work has previously been completed by NASA [6] to identify high risk medical events, pointing out the need for risk assessment and decision support tools. Other work, such as on acute myocardial infraction [7], has demonstrated the feasibility of creating pathology-specific ESDs with quantitative outcome likelihood estimates as a core component of future decision support systems. The present study builds on previous efforts to develop an enhanced medical infrastructure and medical decision support capability for astronauts in long space missions.

The present Medical Condition Requirements Study took form to produce a knowledge base and prototype scenario-based planning tool for improving medical autonomy. The first aim was to identify the medical conditions most likely to rely on medical autonomy for management. The intent was to start with the 100 priority conditions included in the Integrated Medical Model medical condition list (IMCL) [6]. The second aim was to populate a database linking mission-critical human conditions with key causal and associated factors, treatment plans (including required resources, interventions, and reference material), and probable outcomes (summarized using ESDs). The third aim was to organize the information in a PostgreSQL database to allow scenario-based queries that could be used for resource planning (medical infrastructure, supplies, and medical knowledge/skills), and eventually to contribute to an on-board medical decision support system.

## II. Methods

### *A. Group Model Building*

Medical emergencies address complex and dynamic problems, and expert perspectives about their manifestation, management, and likely outcomes can differ considerably. Group model building sessions are a useful way to guide efforts in a productive direction [8]–[10]. Weekly workshops were held over the course of 10 months to analyze autonomy requirements, prioritize medical emergencies, and construct medical condition management and outcome models intended

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for scenario-based planning.

The modeling group included an environmental physiology PhD research specialist and two physicians, a general practitioner with a PhD in physiology/endocrinology and expertise in space medicine research, and an emergency and intensive care physician with an MSc in clinical epidemiology. Graduate and medical students supported the effort and the role of facilitator was filled by a cognitive science expert. Facilitator-guided workshop activities produced individual ratings followed by debate and consensus building (with evidence-based literature reviews completed between workshop sessions for adjudication) [10], [11]. Modeling tools included the MYRIAD multicriteria decision-making software, Excel spreadsheets, and a graph editor for ESD construction.

### *B. Choice of Medical Conditions*

The first step in the creation of this scenario-based query tool was to review the IMCL [6], and develop an approach to define a short list of highest priority medical conditions likely demanding enhanced medical autonomy in the context of an extended duration (e.g., Mars) mission. The panel composed of the three medical science experts established the inclusion and exclusion criteria. Six criteria favoring exclusion from the IMCL were used to perform a first reduction. Seven inclusion factors were then applied to the reduced list (Table I). A medical condition was excluded if it met at least one exclusion criterion or failed to meet at least one inclusion criterion.

TABLE I
EXCLUSION/INCLUSION CRITERIA LIST

| Exclusion Criteria | Inclusion Criteria |
|---|---|
| Likelihood can be reduced (to a probability close to zero) by screening and/or prophylactic care | Condition creates a high risk of functional incapacitation and/or threat to mission |
| Likelihood of development can be reduced dramatically by engineering solutions | Condition is contagious |
| Essential treatment is likely to be completed in <5 min (acute first aid level response) | Condition has a high likelihood of occurring |
| Recovery with little or no treatment and little or no residual effect is likely | Critical treatment is required in the multi-minute to multi-hour window |
| Transient manifestation of space adaptation (requiring minimal treatment) | Treatment in space is different from treatment on the ground |
| Condition is unlikely to be recoverable | Communication frequency (high number of exchanges) |
| | Communication bandwidth (high bandwidth requirement) |

A dichotomous 0 (no) and 1 (yes) score was used for exclusion criteria and a 0-1-2 scale (no/somewhat/yes) was used for inclusion criteria. Three conditions deemed potentially relevant for a long-duration spaceflight were added to the list (acute psychosis, pulmonary embolism, and herniated disk), resulting in a total of 103 conditions from which to create a high priority shortlist. A total of 43 medical conditions were initially excluded from further analysis. Eight conditions from the 60 remaining were removed for failure to meet at least one inclusion criterion. This left 52 conditions to evaluate. A quantitative ranking was completed using the seven inclusion criteria. Weightings (0-10 scale) were assigned to each inclusion criterion (Table II), and then two scoring methodologies were used to identify the top 10 conditions to be addressed in detail.

TABLE II
CRITERIA AND WEIGHTS USED IN THE WEIGHTED SUM MEDICAL CONDITION PRIORITY SCORING METHOD

| | |
|---|---|
| High risk to mission | 10 |
| High likelihood of occurring | 10 |
| Critical treatment time window | 7 |
| Contagious condition | 5 |
| Different treatment in space | 3 |
| Need for high communication frequency | 3 |
| Need for large communication bandwidth | 3 |

The first scoring method employed a simple weighted sum; the sum of individual criterion scores multiplied by the 'weight' assigned to each criterion:

Priority score = (Weight 1 * Criterion 1) + (Weight 2 * Criterion 2) + (Weight 3 * Criterion 3) + (Weight 4 * Criterion 4) + (Weight 5 * Criterion 5) + (Weight 6 * Criterion 6) + (Weight 7 * Criterion 7)

The second scoring method can be described as a "weighted sum with interactions". The MYRIAD multicriteria decision-making support tool was used for this. MYRIAD is a preference-modeling tool developed by Thales to address limitations of linear models [12]. MYRIAD enables a non-linear aggregation of criteria to combine disparate measures into a coherent assessment evaluating multiple key logical relationships between metrics – ones that may not be effectively modeled using a traditional weighted sum approach. The two approaches produced very similar top 10 rankings (Table III).

TABLE III
TOP 10 PRIORITY RANKINGS BY TWO SCORING METHODS

| Prioritization | MYRIAD | Weighted sum |
|---|---|---|
| Acute coronary syndrome | 1 | 1 |
| Sepsis | 2 | 4 |
| Stroke | 3 | 3 |
| Visual impairment and increased intracranial pressure (VIIP) | 4 | 2 |
| Pulmonary embolism | 5 | 5 |
| Nephrolithiasis (renal colic) | 6 | 7 |
| Retinal detachment | 7 | 7 |
| Atrial fibrillation/flutter | 8 | 8 |
| Eye penetration (foreign body) | 10 | 9 |
| Herniated disk | 9 | 15 |

The strength of the MYRIAD method is the built-in functions that help modelers/facilitators extract stakeholder and/or subject matter expert knowledge without requiring specific mathematical expertise (Choquet integral) [13].

### *C. Scoping Review*

Once the top 10 medical conditions list was established, a two-pronged literature review was performed. A review of Earth-based literature was completed using Uptodate and

JAMA Rational Clinical Examination series. A scoping review of space literature accessed Medline Ovid, Embase, PsychInfo, Web of Knowledge, Aerospace Research Central, and IEEE Xplore databases. The scoping review queries were prepared by an information specialist. Flagged items were evaluated by multiple reviewers to determine relevancy.

### *D. ESDs*

ESDs for each of the top 10 conditions were developed using the probabilistic graphical model inspired from Bayesian networks [14], [15]. The product can be best described as directed acyclic graphs. Using Draw.io diagramming software (JGraph Ltd., Northhampton, UK), ESDs were developed starting with the diagnosis of the medical condition on top and flowing downward through possible interventions to end at outcome nodes. ESDs were created and revised based on the clinical experience of the research group and consulting colleagues, published evidence, and best practice consensus. Medical condition summaries included the diagnostic and therapeutic tools and skills required to manage each condition. The ESDs were intended to represent all diagnostic and therapeutic tools that could be available to provide a comprehensive summary of the path that could be available in future long-term missions. Fig. 1 illustrates the ESD for acute coronary syndrome (ACS).

Three outcome categories were designated as: 1) full recovery (FR), 2) partial recovery (PR), and 3) death or severe incapacitation (DI). To assess the outcomes of scenario-based queries, ESD nodes involving either diagnostic or treatment elements were linked to associated requirement lists.

ESDs were implemented into the medical condition database as computational models. As such they also contain probability parameters for: 1) treatment success/failure, 2) decision nodes (i.e., situation variables that will affect treatment options), and 3) different outcomes if more than one is identified in an outcome node.

Square nodes correspond to condition name (this root node also corresponds to the starting point after diagnosis) and interventions (shaded in green). Blue diamond nodes correspond to decision points that will alter treatment options (depending on the situation variables described within these nodes). Orange nodes correspond to outcomes. Visualization techniques involving colors and shapes of nodes allow direct categorization of node types and express differences in meaning (Fig. 1) [16], [17]. All ESDs were produced with a similar decision tree and outcome structure.

For a diagnostic or specific intervention to succeed, specific requirements must be met. Requirements lists were developed using evidence-based information from the knowledge base. Requirements lists specified the level of knowledge, skills, medical technologies, and supplies mandatory for diagnosis and/or treatment. Hyperlinks joined the ESDs to Google Spreadsheet files (Google, Mountain View, CA, USA) for quick access.

### *E. Requirements Analysis Tool*

A key utility of a queryable database is that it can be used as a scenario-based planning tool to compare the impact of differences in medical infrastructure (knowledge, skills, equipment, and/or supplies). The present effort built upon previous work [1], [2] and thus, continued using a PostgreSQL relational database management system to implement a scenario-based query capability. Scenario-based queries require formal capture of the logic of each ESD model and importation of the logic into the medical condition database. Probabilistic outcomes could be assigned to each path as a function of scenario/query parameters.

The tool was structured for flexibility to accommodate new or modified parameters as knowledge, technology and medical practice evolve.

### *F. Outcome Likelihood Metric*

A likelihood score could be established for three outcome possibilities (full recovery, partial recovery, or death/severe incapacitation). An overall metric of “health outcome” was then computed to facilitate comparison of outcomes of different scenario-based queries. For example:

$$\text{Health outcome} = 100 * (FR*1 + PR*0.5 + DI*0)$$

Using the above formula, the likelihood of each potential outcome (FR, PR, DI) is multiplied by a weight to produce the overall health outcome. This metric, ranging from 0 to 100, is at maximum if the sole outcome is full recovery, 50 if the sole outcome is partial recovery, and 0 if the sole outcome is death/severe incapacitation.

## III. Results

### *A. Medical Condition Database*

During the initial requirement review phase, a total of 103 medical conditions were reviewed based on a series of inclusion/exclusion criteria defined by the team to help prioritize conditions in terms of the need for medical autonomy in space exploration missions. Over 1000 criteria judgments were performed by the panel of three medical science experts. Multicriteria decision-making methods were used to calculate overall priority scores for a list of 60 non-excluded conditions and the top 10 medical conditions were focused on for content development. The literature search provided varying amounts of information for the prioritized conditions, addressing differential diagnosis, investigations, and treatments of the targeted events.

The added complexity of the MYRIAD method did not substantially alter the outcome since priority rankings from the two methods generally converged for the highest ranked conditions. Divergent rankings were observed for lower priority conditions (not presented).

The main result was the creation of 13 ESDs for 10 medical conditions. Composed out of the mixture of medical condition summaries, diagnostic, treatments, skills and ESDs, the resulting logical model can be used to perform scenario-based queries. PostgreSQL views (queries) where scripted to create infrastructure requirements analyses exploring different scenarios as inputs and returning health outcomes as results.

Notional probabilities were assigned to each of the three types of nodes as 50/50% (success/fail, yes/no, first/second outcome), reflecting the relative absence of medical data specific to prolonged space missions. Flexible architecture was implemented in the database to allow future revision as relevant data become available.

*B. Scenario-Based Query Results*

Scenario-based queries can be used to compare different hypothetical choices of medical infrastructure. By removing any part of the necessary medical infrastructure, the available intervention paths and potentially the predicted outcome can change. A total of 27 scenario-based queries were performed and summarized herein to illustrate the types of insights that can be derived from it. The health outcome values (on a scale from 0 to 100), shown in Tables IV, V and VI demonstrate how different queries can yield very diverse health outcome likelihoods. Each column is the result of a different query.

TABLE IV
PREDICTED HEALTH OUTCOME FOR DIFFERENT LEVELS OF REQUIREMENT SATISFACTION

| Medical Condition | All requirements | No requirements | Diagnostic requirements only | Without specialist knowledge |
|---|---|---|---|---|
| Nephrolithiasis | 39 | 25 | 25 | 21 |
| Stroke | 27 | 25 | 25 | 25 |
| Retinal detachment | 64 | 25 | 29 | 25 |
| Atrial fibrillation/flutter | 16 | 0 | 0 | 3 |
| Eye penetration | 25 | 25 | 25 | 20 |
| VIIP | 81 | 50 | 81 | 50 |
| Herniated disk | 57 | 31 | 27 | 48 |
| Gas embolism | 61 | 0 | 0 | 56 |
| Fat embolism | 70 | 33 | 33 | 70 |
| Blood clot embolism | 13 | 0 | 0 | 8 |
| ACS (NSTEMI) | 15 | 0 | 0 | 9 |
| ACS (STEMI) | 12 | 0 | 0 | 4 |
| Sepsis | 28 | 0 | 0 | 28 |
| Mean | 39 | 16 | 19 | 28 |

TABLE V
PREDICTED HEALTH OUTCOMES ASSOCIATED WITH THE AVAILABILITY OF SPECIFIC SKILLS

| Medical Condition | All Requirements met | General anesthesia | Phlebotomy | ACLS | Lab test capability | Local anesthesia |
|---|---|---|---|---|---|---|
| Nephrolithiasis | 39 | 28 | 25 | 38 | 25 | 29 |
| Stroke | 27 | 20 | 25 | 22 | 27 | 26 |
| Retinal detachment | 64 | 51 | 64 | 64 | 64 | 60 |
| Atrial fibrillation/flutter | 16 | 9 | 0 | 0 | 0 | 16 |
| Eye penetration | 25 | 24 | 25 | 25 | 25 | 22 |
| VIIP | 81 | 81 | 50 | 81 | 50 | 50 |
| Herniated disk | 57 | 47 | 57 | 57 | 54 | 57 |
| Gas embolism | 61 | 57 | 0 | 57 | 61 | 61 |
| Fat embolism | 70 | 65 | 33 | 65 | 33 | 70 |
| Blood clot | 13 | 9 | 0 | 13 | 0 | 8 |
| ACS (NSTEMI) | 15 | 11 | 0 | 11 | 0 | 11 |
| ACS (STEMI) | 12 | 7 | 0 | 8 | 0 | 6 |
| Sepsis | 28 | 0 | 0 | 19 | 0 | 28 |
| **Mean** | **39** | **31** | **21** | **35** | **26** | **34** |

Table IV shows the results of four scenario-based queries, reporting the health outcome metric by medical condition and on average. This metric merges into a single value the likelihood of the three possible outcome severities (FR, PR, DI). The first query assumes that all the knowledge, skill and medical supply requirements are satisfied. The second query depicts a scenario in which no requirements were satisfied. The third query assumes that only the knowledge, skills, or supplies required for the medical condition diagnosis are available (which incidentally may allow some of the interventions to succeed as well). The fourth scenario shows results when all required knowledge, skills and supplies are available except for medical specialist knowledge. The specific health outcome values obtained were based on the 50/50 probability assumptions for all ESD branching paths (described in the method) used in the development of this prototype system. The analysis described herein thus focused on demonstrating that the tool can show differential impacts of various medical infrastructure scenarios on crew health outcomes.

The differential impacts across the columns (Tables IV-VI) indicate what elements of the medical infrastructure need to be prioritized to achieve the best possible health outcomes (more full recovery and partial recovery likelihoods and less death/severe incapacitation likelihoods). For example, in Table IV, the predicted health outcome in the advent of a gas embolism is 61 in conditions where all requirements are fulfilled, in contrast to 0 if no requirements are met. The mean health outcome at the bottom of the table provides a sense of the overall impacts of different medical infrastructure scenarios across the range of medical conditions included.

Tables V, VI show the results of the baseline scenario-based query (all requirements met) plus five other queries out of 21, each removing from the medical infrastructure one specific skill (Table V) or medical supply/technology (Table VI) and showing impacts across all medical conditions. Using sepsis as an example, the model predicts that not having a general anesthesia skill drops the predicted health outcome from 28 to 0, while the lack of ACLS skills would reduce the predicted health outcome from 28 to 19. The "all requirements met" column is used as the reference for estimating impacts of different medical infrastructure conditions.

TABLE VI
PREDICTED HEALTH OUTCOMES ASSOCIATED WITH THE AVAILABILITY OF SPECIFIC MEDICAL SUPPLIES OR TECHNOLOGY

| Medical Condition | All requirements met | Basic medical equipment | Basic medical supply | Sedatives | Narcotics | ACLS |
|---|---|---|---|---|---|---|
| Nephrolithiasis | 39 | 25 | 25 | 38 | 25 | 36 |
| Stroke | 27 | 25 | 25 | 17 | 25 | 22 |
| Retinal detachment | 64 | 51 | 37 | 51 | 51 | 64 |
| Atrial fibrillation/flutter | 16 | 0 | 0 | 9 | 0 | 9 |
| Eye penetration | 25 | 25 | 25 | 25 | 25 | 25 |
| VIIP | 81 | 50 | 50 | 81 | 81 | 81 |
| Herniated disk | 57 | 31 | 31 | 47 | 30 | 51 |
| Gas embolism | 61 | 0 | 0 | 57 | 57 | 57 |
| Fat embolism | 70 | 33 | 33 | 65 | 65 | 65 |
| Blood clot | 13 | 0 | 0 | 13 | 13 | 13 |
| ACS (NSTEMI) | 15 | 0 | 0 | 11 | 0 | 11 |
| ACS (STEMI) | 12 | 0 | 0 | 7 | 0 | 8 |
| Sepsis | 28 | 0 | 0 | 19 | 19 | 0 |
| **Mean** | **39** | **18** | **17** | **34** | **30** | **34** |

TABLE VII
SUPPLIES REQUIRED IN THE MANAGEMENT OF AT LEAST SEVEN OF THE TOP 10 MEDICAL CONDITIONS

| Medical supply (disposable, instrument, or support machine) | Number of conditions |
|---|---|
| Basic medical equipment | 10 |
| Basic medical supplies | 10 |
| Sedatives | 9 |
| Narcotics | 9 |
| ACLS equipment | 8 |
| Venous blood draw kit | 8 |
| Hematology analyzer | 8 |
| IV line | 8 |
| Fluids | 8 |
| Antiemetics | 8 |
| Biochemistry analyzer | 8 |
| Ultrasound probe, linear array | 7 |
| Suction catheter | 7 |

One utility of this system is the ability to generate a report of the number of medical conditions in the database that would likely require any particular skill, supply, or tool. Results from such queries could help in resource planning for space-exploration missions. This assessment will not provide an estimate of the likelihood of needing the capabilities or the impact of their absence.

Table VII presents the supplies expected to be required to manage at least seven of the top 10 medical conditions. Basic medical equipment was found to be needed in every medical condition of the list. Similarly, Table VIII presents the skills expected to be required to manage at least five of the top 10 medical conditions. General anesthesia was expected to be required for nine out of the 10 conditions. Effectively, Tables VII, VIII show the extent to which specific equipment or skills are needed to increase chances of favorable health outcomes across the set of medical conditions considered.

TABLE VIII
SKILLS REQUIRED IN THE MANAGEMENT AT LEAST FIVE OF THE TOP 10 MEDICAL CONDITIONS

| Skill | Number of conditions |
|---|---|
| General anesthesia | 9 |
| Phlebotomy | 8 |
| ACLS | 7 |
| Lab test | 7 |
| Anesthesia, local | 7 |
| Advanced airway management | 7 |
| IV line preparation | 6 |
| Medication | 6 |
| IV catheterization | 6 |
| IV infusion pump | 6 |
| Ventilator settings and parameter adjustment | 5 |
| Ultrasound | 5 |

## IV. DISCUSSION

### A. Medical Requirements Analysis Tool

The Medical Condition Requirements Study has contributed to needs/priority analysis, knowledge acquisition, decision process modelling, and technology development. The ESD formalism was adapted and extended for the purpose of characterizing likely outcomes of medical conditions as a function of the available medical knowledge, skills and supplies in a given mission scenario. A PostgreSQL database framework was designed and implemented to support scenario-based queries.

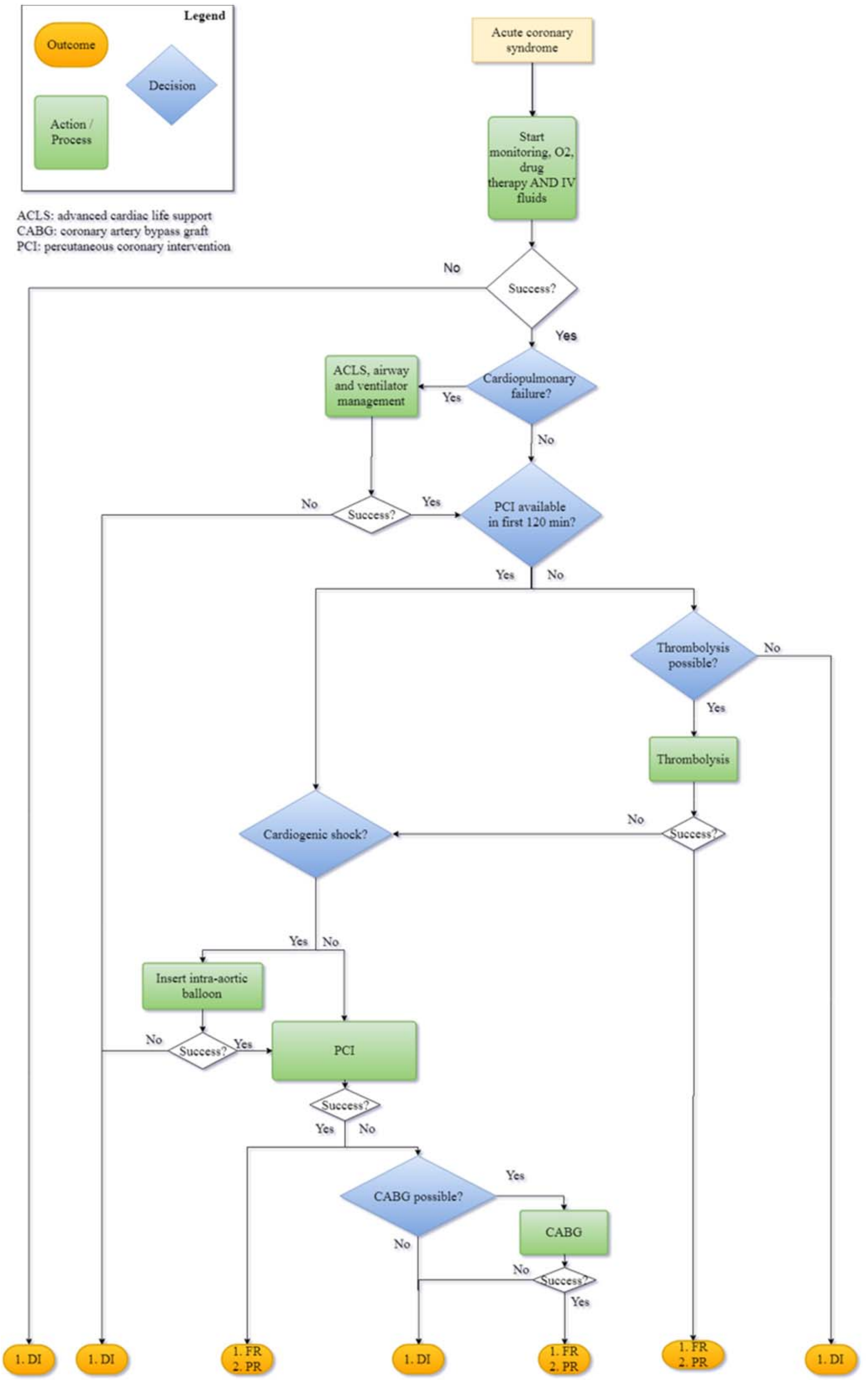


Fig. 1 Acute coronary syndrome ESD

Using a PostgreSQL relational database management system offers the possibility to integrate the current work with previous work (performed by Douglas R. Hamilton Research and Development Corp. for CSA). The new scenario-based query capability allows specifying (using PostgreSQL query syntax) a given medical infrastructure (availability of knowledge, skills, and medical supplies) to obtain expected health outcomes for each medical condition. Three types of outcomes were defined in the ESD models and database (FR, PR, DI). A query can return the likelihood of each outcome by running through the logic of the ESD model and cross-checking for requirements and path probabilities. Scenario-based queries can be used to compare health outcomes with or without specific elements of the medical infrastructure to help in mission and materiel planning.

### B. Limitations

The template is in place, but substantial effort is required to address the conditions not prioritized in this effort. The utility of the system to aid in both mission planning and medical autonomy requires substantial expansion of the knowledge content.

Additional experience, much of which can only be gained by prolonged space missions, is necessary to define more realistic path probabilities into the ESD models. The current database allows for the stated probabilities to be changed, but real experience is needed for meaningful assessment of assumptions and probabilities. The current probabilistic assumptions (50%-50% probabilities for each ESD node) are placeholders. While the available evidence to estimate quantitative likelihoods is mostly lacking, likelihood estimates could be generated by expert panels as an initial effort to “calibrate” the tool for mission planning use.

Scenario-based query results reported in this study show the likely outcome severity (given current probability assumptions). However, for planning and decision making purposes, factoring in the probability of occurrence of each medical condition would give a better overall sense of the priority of medical infrastructure elements. While an equal likelihood of occurrence is assumed here, weighting factors could be applied to alter the frequency with which individual medical emergencies would be expected to occur during missions. This extension could be embedded into the database or simply added to a results dashboard allowing users to change likelihoods to observe the weighted outcomes.

Finally, further input from specialist medical experts is needed to help refine ESDs, particularly to address evolving practice and medical capabilities.

### C. Direction for Future Work

A valuable next step in the development of this tool would be enhancement of the scenario-based querying process by adding a user interface to allow queries without the need for PostgreSQL query syntax. This could take the form of a web interface that allows the user to specify which medical infrastructure elements are available and comparing the health outcomes of different scenarios. Filters and views could also be implemented to support a variety of exploratory queries.

The PostgreSQL database, conditions summaries, ESDs, and requirement documents could be used for training and medical decision support system purposes. Different user interfaces would have to be developed and tested for such functionality to be established. Artificial intelligence algorithms could also access the databases and ESDs to support medical decision making. For long term exploration missions such as missions to Mars, other authors [18] have suggested that virtual reality and augmented reality could potentially offer the possibility for on-site and on-demand training for various medical procedures in the future.

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