

CENTER FOR INFORMATION INTEGRITY RESEARCH

B-64 (FF), Gulmohar Park, New Delhi- 110 049, India
E-mail: vmandke@unitechsys.com; vijaymandke@satyam.net.in

MAKING A CASE FOR I*I IN HEALTHCARE EXAMPLE - 1

Vijay Mandke

Abstract: The white paper presents a medical error example, which revolves around the issue of nature of knowledge factors required in healthcare problem solving. Given the open system view of a healthcare system, error here is of not *originating* correctly important, but less obvious information requirements of the case. This leads to loss of Information Origination Integrity resulting in delivery of unsafe healthcare.

1 A real life example: Anesthetic Error resulting in Loss of Healthcare Goal Integrity

When patients get treated for their ailments, they reasonably expect that their health condition will improve, or, at the least not deteriorate. This is a requirement of goal integrity between supplier (i.e., healthcare systems and components), process (i.e., treatment) and customer (i.e., patient). Medical literature examines a corpus of cases in anesthesiology; one is as follows [2,3].

1.1 Case description: A Vascular Surgery inflicting patient with a Myocardial Infarction

“An elderly patient presented with a painful, pulse less, blue arm indicating a blood clot (embolus) in one of the major arteries that threatened loss of that limb. Emergency surgery to perform removal of the clot (embolectomy) was clearly indicated. The patient had a complex medical and surgical history with high blood pressure, diabetes, requiring regular insulin treatment, a prior heart attack, and previous coronary artery bypass surgery. The patient also had evidence of recently worsening congestive heart failure, that is, shortness of breath, dyspnea on exertion and leg swelling (pedal edema). Electrocardiogram changes included inverted T waves. Chest X-ray suggested pulmonary edema. The arterial blood gas showed markedly low oxygen in the arterial blood (p_aO_2 of 56 on unknown F_iO_2). The blood glucose was high (800). The patient received furosemide (a diuretic) and 12 units of insulin in the emergency room. The patient was taken to the operating room for removal of the clot under local anesthesia with sedation provided by the anesthetist. In the operating room the patient’s blood pressure was high, 210/120; a nitroglycerin drip was started and increased in an effort to reduce the blood pressure. The arterial oxygen saturation (S_aO_2) was 88% on nasal cannula and did not improve with a re-breathing mask, but rose to the high 90s when the anesthesia machine circuit was used to supply 100% oxygen by mask. The patient did not complain of chest pain but did complain of abdominal pain and received morphine. Urine output was high in the operating room. The blood pressure continued about 200/100. Nifedipine was given sublingually and the pressure fell over 10 minutes to 90 systolic. The nitroglycerin infusion rate was decreased and the pressure rose to 140. The embolectomy was successful. Post-operative cardiac enzyme studies showed a peak about 12 hours after the surgical procedure, indicating that the patient had suffered a myocardial infarction (heart attack) sometime in the period including the time in the emergency room and the operating room. The patient survived.”

2 What Went Wrong? - Loss of Information Integrity

What went wrong? Was it the error in medical prescription first by the physicians who saw the patient initially, and then by the anesthetist or error in surgical procedure or in procedures pursued by the anesthetist? Or was the error due to lack of skill on the part of participants? No, all such are post-event observations. In fact to the peer review that followed after the incident it was apparent that many of the practitioner's actions were appropriate in the context of the case as it evolved. For example, the level of oxygen in the blood was low and the anesthetist pursued several different means of increasing the blood oxygen level, including the use of oxygen by mask.

What really went wrong is all through the course of the vascular surgical treatment the practitioner assumed patient's intravascular volume as "high" as already validated for patients with high signs of congestive heart failure and the information processing operative in the context was not geared to anticipate information error, i.e., loss of Information Integrity (I*I) [5].

3 Information Origination Errors and Loss of Information Integrity

Error here is of not *originating* correctly important, but less obvious information requirements of the case [1,2,3].

3.1 Resulting in Loss of Healthcare Information Content Integrity and Healthcare Goal Integrity at Physician Level

High increased intravascular volume is often present in patients with signs of congestive heart failure. In this case, condition of congestive heart failure was present with other (system environmental) factors including those of high blood glucose and the prior treatment with a diuretic. This indicated that *the* patient's intravascular volume is "low." The fact that the blood pressure fell much further than intended was probably the result of depleted intravascular volume, which was, in turn, the result of the high urinary output provoked by the previous diuretic and the high serum glucose level. It is this information of "low" intravascular volume (and not "high"), which the physicians who saw the patient initially did not *originate*. This information was to be originated *endogenous* to the healthcare decision situation and error here produced incorrect information content leading to loss in Healthcare Information Content Integrity. This information *origination* error and the resulting loss of Content Integrity at physicians' level made the treatment *recipient*, i.e., the patient susceptible to a heart attack; thereby signifying loss of Healthcare Goal Integrity right in the initial stage.

3.2 Resulting in Loss of Treatment (i.e., Process) Integrity at Anesthetist's Level

Many of the practitioner's actions were appropriate in the context of the case as it evolved. To reinforce this observation further, the blood pressure was high, and this was treated, first with nitroglycerin (which may lower the blood pressure but also can protect the heart by increasing its blood flow) and then with nifedipine. However, the practitioner assumed the information processed by physicians in respect of the nature of the patient's intravascular volume as correct. The information processing flaw in his case is, in ballistic behavior, taking (information) decision on "high" intravascular volume as correct and, not to anticipate, in the wake of the combination of congestive heart failure with high urine output from high blood glucose and a diuretic drug (furosemide) and in the wake of change in operable goal, errors in *origination* of information requirements; i.e., loss Process Integrity in treatment administration. In a post-incident review, other practitioners argued that the patient probably should have received more intravenous fluid to replenish the low intravascular volume.

3.3 Resulting in Loss of Treatment Monitoring Integrity

In the opinion of anesthesiologist reviewers of this incident shortly after it occurred, the circumstances of this case should have brought to mind a series of questions about the nature of the patient's intravascular volume. The inability to answer those questions would then have prompted the use of particular monitoring techniques before and during surgical procedure. For example, presence of (system environmental) factors in combinational form indicated that *the* patient should have been monitored invasively to allow precise determination of when enough fluid had been given (e.g., a catheter that goes through the heart and into the pulmonary artery). Not having *originated* these information requirements handicapped this entire treatment with loss of Monitoring Integrity, resulting in inability to anticipate impending myocardial infarction.

3.4 Resulting in Loss of System Integrity and Delivery of Unsafe Treatment

Instead of organizing vascular surgery treatment system for patient with “low” intravascular volume, this resulted in a vascular surgery treatment system meant for a patient with “high” intravascular volume. Thus there was loss of System Integrity resulting in an unsafe treatment for *that* patient.

4. A Case for a paradigm shift: Informational View of Healthcare System

Recognition of above facts warrants paradigm shift in modeling the healthcare system operative in the exemplar incident.

4.1 Treatment Information processed as function of Condition of Recipient

Clearly, what emerges is that, in addition to (a) source or point of origination of information (on the nature of the patient's intravascular volume), which in this case is information processing by the physicians and anesthesiologist, and (b) in addition to the processor of information, i.e., information decision for *use* of the patient, which here is the vascular surgery treatment line administered, the information processed has turned out to be function *also* of (c) recipient, i.e., the patient, or rather of condition of the *recipient*, who in this case has condition of congestive heart failure present along with other (system environmental) factors including those of high blood glucose and the prior treatment with a diuretic.

4.2 Consequence of chain of multiple events with complex error mechanism

Stated differently, the vascular surgery treatment failure then can be seen as that due to the chain of informational errors in the settings of treatment design, administration and monitoring. Specifically, these errors are at the information origination and processing stages under each of these settings. It is these information errors that in combination with the system environmental factors formed complex error mechanisms. Even though the embolectomy was successful, this led to the patient suffering a myocardial infarction (an adverse event (AE)), rendering the healthcare delivered unsafe.

4.3 A basis for informational view of healthcare system

Above calls for informational definition of system. Specifically, every material object contains no less than an infinity of system environmental factors, i.e., facts, which are data and, when processed, information, and, therefore, possible systems. Given the system goal, what is required is to *cull out* – not necessarily physically, but mathematically – and study facts (data and information variables) that are relevant to the identified system goal (Usefulness factor). For example, in the exemplar incident, in addition to all details of the material description of the vascular surgery treatment systems and components for a patient with the condition of congestive heart failure, it was critical to (mathematically) *cull out* other not so obvious system environmental conditions of: high serum glucose level, previous diuretic treatment, high urinary output, depleted intravascular volume and falling of blood pressure much further than intended.

In fact it is when interdependence between these system environmental factors is studied that it becomes easier to establish the “low” nature of the patient’s intravascular volume thereby improving the healthcare information Content Integrity. This in turn lays the path for improving vascular surgery Process Integrity and System Integrity and thus provides a basis for delivering a safe healthcare to *the* patient under consideration [5].

4.4 Open System View of Healthcare System

In other words, for competitive advantage, it is required that systems such as healthcare are modeled in recognition that, whatever else they do, they necessarily process information. This is an open system view as it is open system, which pursues goal, possesses porous boundary with its environment, and processes (i.e., imports and exports) information with its environment [4]. Figure (1) gives a system’s representation of transformation of vascular surgery treatment system as open system.

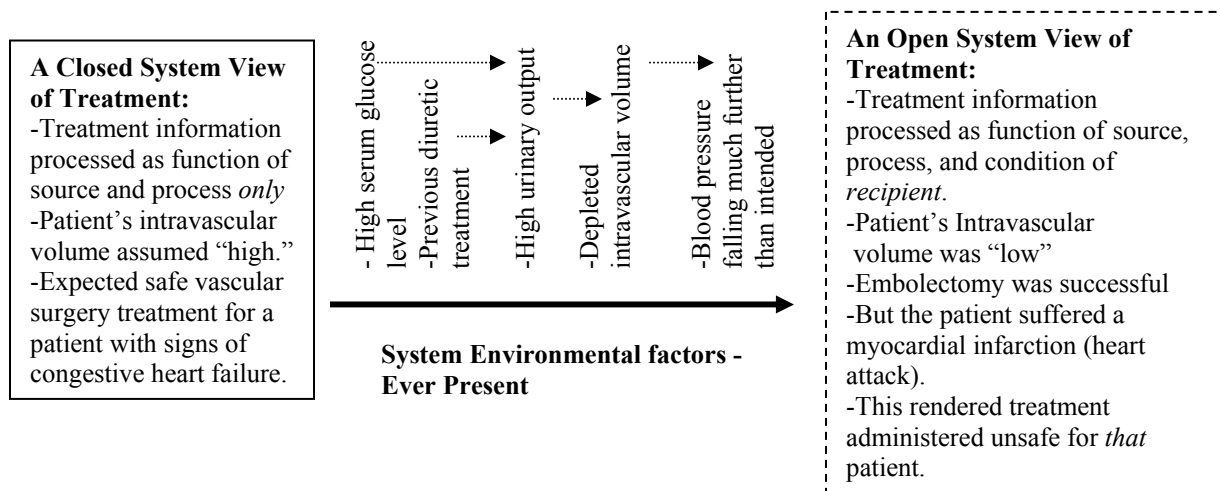


Figure (1): System’s representation of transformation of Vascular Surgery Treatment as Open System

5 Emerging insight – Controlling origination & processing of correct information, i.e. controlling I*I for Effective Healthcare Management

From above, it follows that in the face of ever-present system environmental factors *it is not acceptable that healthcare information is assumed correct, once validated, and that information processing, in ballistic behavior, does not anticipate information error*. Specifically, in the exemplary incident, it is by controlling (i.e., improving) healthcare information Content Integrity, healthcare Goal Integrity, Treatment, i.e., Process Integrity, Treatment Monitoring Integrity, and System Integrity that the vascular surgery treatment implementation could have avoided myocardial infarction and rendered safe and reliable healthcare service for *that* patient. This would have also delivered competitive advantage to the treatment’s internal customers and to the healthcare enterprise as a whole. This presents Information Integrity (I*I), i.e. *correctness* requirement of information, as a controlling factor for adding value to healthcare management.

6. Systems approach to I*I Technology implementation in Healthcare industry

Medical literature search makes it clear the error is common in medical systems [5]. Precise data on the extent of information errors is just not available and bound to vary from system to system, depending on how error is defined. Literature reports one study across various types of systems, which attributes 40% of errors to material, electrical, and mechanical failures. The remaining 60% are attributed to information errors, which is a quantitative pointer to their overbearing nature and a recognition of need for their reduction in system development and implementation life cycle [5,8]. Even then there may be a concern as to how serious is the issue of seemingly indirect consequences of errors as in case of the exemplar incident. Unfortunately, it is very serious, too. Assuming that medication ordering, dispensing, and administration system were 99.9% error free, literature reports a hypothetical example suggesting over 4000 errors per year in an average-sized (600-bed) teaching hospital, and if only 1% of these result in an adverse event (AE), this commendably low rate would still cause 40 AEs from medication alone [1].

6.1 Inadequacy of Data Integrity and Quality Approaches

Traditionally, the problem of error reduction is approached assuming “exactness” requirement. That is error is seen as of that moment having no significance beyond itself. This approach, ad-hoc in nature, puts whole attention after a particular error. For example, in the exemplar incident, practitioners’ entire integrity effort at each stage can be seen to have been focused just on the information requirements of condition of ‘congestive heart failure’ and assuming that nature of the patient’s intravascular volume is “high”. It would not be wrong to say practitioners would have been ‘surprised’ were they to recognize (i.e., originate information) that volume in fact is ‘low’.

Given this, the practitioners, as also observed in Sub-section (3.2), did take *quality* actions in the context of the case. To detail an instance, the level of oxygen in the blood was low and the anesthetist pursued *several* different procedures for increasing the blood oxygen level, including the use of oxygen mask (see Section (2)). In the wake of *incorrect production of information* on the nature of the intravascular volume, however, this rigorous adherence to quality procedures was of no avail. The embolectomy was successful, but the patient suffered a myocardial infraction (an adverse event (AE)), rendering the healthcare delivered unsafe. For the successful application of the appropriate quality procedures the *correct production of information*, i.e., Information Integrity was, thus, fundamental. Following post-incident comments of a senior anesthetist dramatize this limitation of the quality paradigm [3]:

This man was in major sort of hyperglycemia and with popping in extra Lasix [furosemide] you have a risk of hypovolemia from that situation. I don’t understand why that was quietly passed over, I mean that was a major emergency in itself.....This is a complete garbage amount of treatment coming in from each side, responding from the gut to each little bit of stuff [but it] adds up to no logic whatsoever.

Data integrity, auditing solutions, process-centered quality paradigm, noise reduction based communication system technologies; applications of expected utility theory, etc. are examples of this approach. They are all concerned with ensuring consistency of internal objects of databases. In the real world, the error, however, is concerned with “correctness” requirement of information and accordingly it does not occur again in the same form and in the same situation in a linearly predicted manner as was bitterly experienced by the practitioners in the exemplar incident. As a result, this approach costs less, is easier to pursue, and gives a false sense of having taken steps for error removal. It never minimizes the error occurrence, though, and is invariably found less effective in the long run [6].

6.2 Information Integrity based Systems Approach

As evident from Section (5), what is required is a systems approach, which sees design of objects, activities, rules and procedures, norms, commands, and patterns of behavior as being the source of errors [4,7]. Clearly, systems approach is holistic, more in tune with the setting in which the real world operates. It does not see the error as, say, a “medical” problem, but as that of (or more correctly as that of loss of) Information Integrity (I*I), that is trustworthiness and dependability (here say in a “medical” setting), of: content and process; of each of the system components as also the complete system (Section (3)); of each of system development & implementation phases of design, development, testing, implementation, and maintenance as also the total lifecycle model. This emphasis on I*I of component (or phase) as also of complete system (or total lifecycle) is important in that it also suggests requirement of I*I in respect of relations and interactions between the components and between the phases. Only when this entirety of I*I requirement is ensured will the error be minimized.

6.3 Needed I*I Processing initiatives

In concrete terms, open system view of a healthcare system (Section (5)) facilitates modeling a healthcare business process as integral to a continuous individual information *originating* and processing situation in the presence of uncertainty. Uncertainties are due to the ever-present system environmental factors of complexity, change, communication, conversion, and corruption (5”C”s). As illustrated through Section (3), this healthcare process *IS* view is a multistage decision process ridden with information origination and processing errors at all stages [4]. Ensuring integrity of information *origination* process calls for I*I processing initiatives in respect of: (i) operable patient healthcare goal, (ii) *culled out* (useful) healthcare information variables, (iii) interdependencies between *culled out* information variables, (iv) forecasting models of *culled out* information variables; and (v) information structure dynamics model.

This is followed by information processing, which is unstructured and a periodic. For effective system performance, this information processing also calls for further I*I processing initiatives in respect of: (vi) current basis input data in the form of healthcare requirements of the patient under consideration, healthcare system capabilities and costs, questions, etc; (vii) processing of input data through information structure dynamics model at (v) so as to deliver flexible (customized) patient healthcare information decision, (viii) control system providing input, process and output controls to the healthcare process, and, finally, (ix) healthcare plant input, process, and output, i.e., the healthcare product/system/service delivered to patient [5,6].

This is the totality of I*I Technology development space applicable to entire range of activities across strategic, managerial (control) and operational levels. Thus what healthcare industry and professionals have before is a vast I*I Technology development market space in the healthcare service domain.

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