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# MAKING A CASE FOR I*I IN HEALTHCARE EXAMPLE – 2

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**Abstract**: The white paper titled "Making A Case for I*I in Healthcare Example – 1" considered the issue of the nature of knowledge factors. Given the open system view of a healthcare system, there the error was of not *originating* correctly important, but less obvious information requirements of the case. This led to loss of Information Origination Integrity resulting in delivery of unsafe healthcare.

This white paper shows that when something in the environment is found anomalous (deviating from what is standard, i.e., integrity deviation), it necessitates information recognition. Changing environment necessarily presents complex problem solving situations. Unlike simple laboratory worlds with a "best" choice, real complex systems intrinsically contain *conflicts that must be resolved*. And problem information recognition constitutes a central feature of information origination process model that applies to complex dynamic worlds. This is because it is the implementation of effective information recognition process that goes to facilitate a working model of an open system view of any real world system under consideration.

## 1.A Real life example: Hypotension treatment case modeled as Information Origination Integrity Control Problem for Healthcare Goal Delivery

Healthcare system outcomes are strongly influenced by status of devices, problems of equipment ergonomics, limits of human-computer interaction, decision exigencies from time pressure, etc. [2,3]. Depending on situation complexity and rate of changing environment, the influence factors' list can be endless. I*I research in healthcare shows that such influences result from incorrect origination of information, i.e., from the loss of Information Origination Integrity [5].

### 1.1 Case description

"During a coronary artery bypass graft procedure, an infusion controller device delivered a large volume of a potent drug to the patient at a time when no drug should have been flowing. Five of the microprocessor-based devices were set up in the usual fashion at the beginning of the day, prior to the beginning of the case. The initial sequence of events associated with the case was unremarkable. Elevated systolic blood pressure (>160 torr) at the time of sternotomy prompted the practitioner to begin an infusion of sodium nitroprusside via one of the devices. After the device was started at a drop rate of 10/min, the device began to sound the alarm. The tubing connecting the device to the patient was checked and a stopcock (valve) was found to be closed. The operator opened the stopcock and restarted the device. Shortly after restart, the device alarmed again. The blood pressure was falling by this time, and the operator turned the device off. Over a short period, hypertension gave way to hypotension (systolic pressure < 60 torr). The hypotension was unresponsive to fluid challenge but did respond to repeated boluses of neosynephrine and epinephrine. The patient was placed on bypass rapidly. Later, the container of nitroprusside was found to be empty; a full bag of 50 mg in 250 ml was set up before the case" [2,3].

## 2. What went wrong? – Loss of Information Origination Integrity

It is only after repeated boluses of neosynephrine and epinephrine and after placing the patient on bypass (*in this situation decisions of great medical merit*), it was recognized that the container of nitroprusside (of which a full bag was set up before the case) was empty. Was it the error on the part of the physicians in using the infusion controller devices that led to the emergency as the patient's state of hypertension gave way to that of hypotension? Or was it the wrong assembly of the devices? Or was it the lack of skill or accountability on the part of the pactitioners? No, all such are post event observations.

What really went wrong is all through the evolution of the case (*exc*ept towards the end when choice of drug neosynephrine and epinephrine was decided to counteract the large dose of sodium nitroprusside that the patient was receiving) there were information recognition errors resulting in incorrect production of information. That is there was *loss of or lack (in the sense of non-optimality) of control of Information Origination Integrity* [8].

## 3. Information Recognition Errors and Loss of Information Origination Integrity

Like all real world phenomena the medical events of the hypotension case were evolving. When something in the environment is found anomalous (deviating from what is standard, i.e., integrity deviation), it necessitates *information recognition*, i.e., information origination in respect of that something. To effect an intended competitive advantage, at this point a process of I*I control *must* begin. For open systems this information recognition is an on-going demand and Information Recognition Integrity control is a costly activity in that it requires committing internal and external system resources. For the hypotension case, the errors were *these* 'information recognition' errors [1,2,3,5].

***Device Assembling Process Error resulting into***
***Loss of Device Operation Outcome Integrity leading to***
***Loss of Healthcare Safety Goal Integrity from beginning***

To elaborate, post-incident evaluation found that to begin with itself the infusion controller device was assembled incorrectly. This procedural error leading to loss of process integrity in the device assembly set the device for the operational outcome of "free" flow of drug (instead of drop by drop) from the device. This loss of device-operation-outcome integrity was not medically commensurate with the medical treatment requirement for hypertension. Thus loss of healthcare safety goal integrity and its indirect adverse consequences were built into the case right from the beginning. The information recognition errors were in respect of *not* recognizing this reality.

### 3.1 Initial Information Recognition Error resulting in Loss of Healthcare Information Content Integrity

There was a device assembly error allowing free flow of drug nitroprusside from one of the devices. Specifically, the set-up comprised multiple drug infusion devices. Drugs to raise and lower blood pressure and other cardiovascular system parameters were held in the fluid bags above. The controller boxes regulated flow through the tubing based on the detection of fluid drops in drip chambers connected to the bags. The individual flows were joined together by a series of stopcocks to a single piece of tubing, which was then connected to the patient.

In this set-up one of the devices was assembled incorrectly allowing free flow of drug. Drug delivery was blocked, however, by the corresponding downstream stopcock, which was closed.

**Environmental factors contributing to information recognition error**

The physicians involved in the incident were comparatively experienced device users. But a number of ergonomic factors led to not recognizing the unintended flow of drug via the infusion device. These factors are:

(a) the drip chamber being obscured by the machine's sensor, making visual inspection difficult,
(b) presence of an aluminum shield around the fluid bag, hiding its decreasing size, and
(c) presence of multiple devices, making it difficult to trace the tubing pathways.

This was the initial information recognition error and it led to the physicians assuming that all devices were correctly assembled. This was the loss of healthcare information content integrity, which was detrimental to the patient's healthcare safety in this particular situation.

### 3.2 Alarm System Design Error leading to Communication Error resulting in Information Origination Error

The initial sequence of events associated with the case is as expected. Increased systolic blood pressure (>160 torr) at the time of sternotomy made the practitioner infuse sodium nitroprusside via one of the devices. This device was set for a drop rate of 10/min. But the machine did not detect any flow of drug as the stopcock was closed, triggering visual and auditory alarms. The alarms are designed to indicate either that no drug is delivered or that the device is turned off.

On checking the tubing connecting the device to the patient, the valve was found closed. The operator opened the valve and restarted the device.

In view of the practitioners, now, the drug was being infused at the desired drop rate and should control the blood pressure.

However, the reality was different. When the stopcock (valve) was opened, free flow of fluid containing drug began. The controller was restarted, but the machine again detected no drops because the flow was wide open and no individual drops were formed. The controller alarmed again, with the same message (as earlier), which indicated that there was no flow.

*That is, when fluid flow was wide open, the alarm indicated no flow*. On the part of the communication system that the alarm represents, this is a design error resulting in communication error contributing to incorrect production of information. Acting with delay, in this case, this design error led to information origination error, as when flow in fact was wide open the message delivered was that there is no flow.

### 3.3 Time Pressure leading to Information Recognition Error

Even as there was incorrect production of information due to the design error in the alarm system, *an issue of interest is why the practitioners did not anticipate the error*.

This is because, in reality free flow of the drug being underway, between the opening of the stopcock and the generation of the second time error message, sufficient drug was delivered to reduce the blood pressure. The operator saw (recognized) the reduced blood pressure, concluded that the sodium nitroprusside drip was not required, and pushed the button marked "off." *This powered down the device, but the flow of the drug continued*.

In the external view of the practitioners, the device was "off", therefore not delivering any drug, and therefore not a plausible cause of the hypotension. That is information "device *off* meant non-drug delivery" was assumed to be correct, once validated, and information processing by the practitioners did not anticipate loss of integrity.

Also when they looked at the device, the displays indicated that the device was not delivering drug or later that it had been turned off. Once again the display design was assumed to be correct, once validated, and information processing by the practitioners did not anticipate loss of design integrity.

Could *these* flaws in information processing have been averted? Could the information at these stages have been processed with improved integrity? Given that the practitioners were experienced device users, probably yes, if they could have *correctly* recognized the information <u>that</u> in this particular situation "*off*" meant that *the device was powered down but a path for fluid flow remained open*. However, this information recognition did not take place, as in the wake of fall in blood pressure, which signified a critical threat to the patient, a more demanding situation appeared.

Briefly, the practitioners were now facing two problem situations. These were:

(i) Due to the loss of process integrity right at the stage of device assembling and due to loss of information recognition integrity at subsequent two stages when the alarms sounded, **first**, there was the problem of not recognizing that the device was administering free flow of drug, and

(ii) **Second** there was the problem of hypotension due to the falling blood pressure, which was a critical threat to the patient.

When faced with these two situations, the information processing resources (at the command of the practitioners) got stretched. In the wake of the critical condition that the problem of hypotension created, it demanded the *limited* resource of information processing for information recognition (change of priority and change in treatment to avoid consequences of fall in blood pressure). Further, criticality also created time pressure. This did not allow committing information processing resources to recognize that the device was administering free flow of drug and as a result the said information recognition error continued.

## 4. What Went Right? – Correct Recognition of Information and Benefit from Improvement of Information Origination Integrity

Even as the hypertension changed into hypotension, remarkably, the practitioners intervened in precisely the right way for the condition they were facing. The hypotension was unresponsive to fluid challenge but did respond to repeated boluses of neosynephrine and epinephrine. The choice of drug to increase the blood pressure was ideal to counteract the large dose of sodium nitroprusside that the patient was receiving without the knowledge of the practitioners (incomplete information).

What, therefore, went right is that the practitioners (a) correctly recognized the change in healthcare goal priority and (b) correctly identified the drug to counteract the free flow of drug from the device. There are a number of potential causes of hypotension in the cardiac surgery patient. In this case, as it evolved, successful diagnosis of the cause became less important than successful treatment of the consequences of the problem. There was change of patient healthcare goal priority and the practitioners correctly identified the systemic threat even though they were unable to diagnose the source. This correct recognition of information on (i) operable healthcare goal change, which led to change in the treatment priority, and (ii) on choice of appropriate counteracting drug, resulted in improved Information Origination Integrity delivering safe healthcare and benefiting the patient.

## 5. Open System View of the Hypotension Case

Hypotension case modeled as above suggests an informational view of a healthcare system. This is an open system view under which each of healthcare systems, their sub-systems and their components pursues goal, possesses porous boundary with its environment and necessarily processes information [7]. Figure (1) gives systems representation of transformation of the hypertension case into the hypotension case through various stages of the exemplar incident.

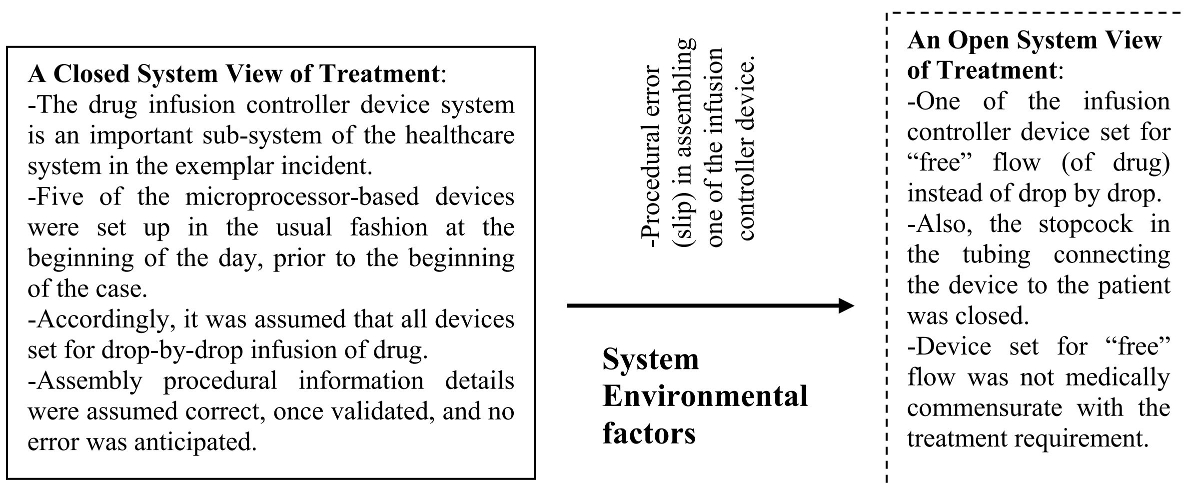


**Figure (1-a): Procedural Error in Device Assembling leading to Loss of Device Operation Outcome Integrity resulting in Loss of Healthcare Safety Goal Integrity from the beginning**

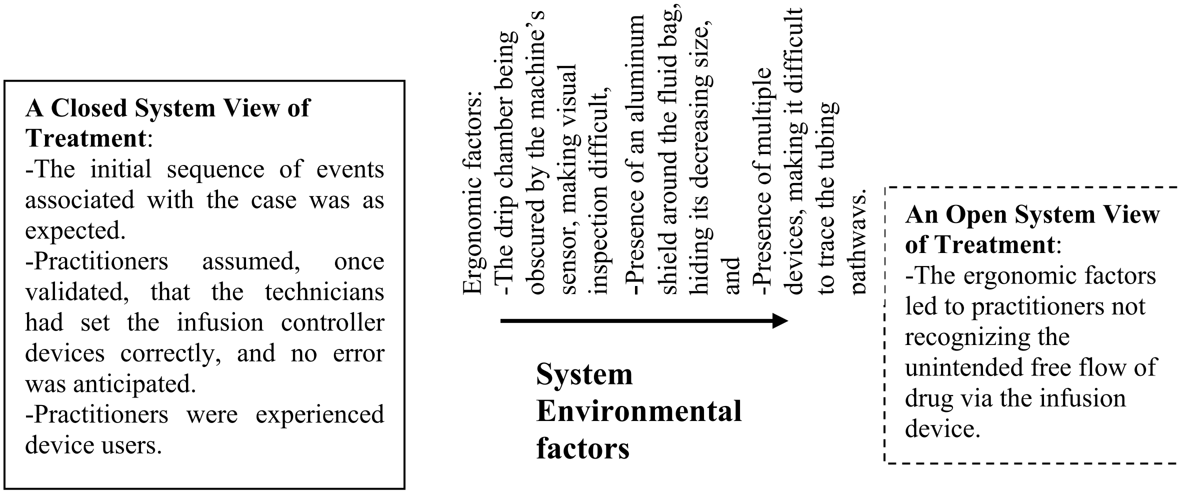


**Figure (1-b): Initial information recognition error leading to loss of Information Origination Integrity**

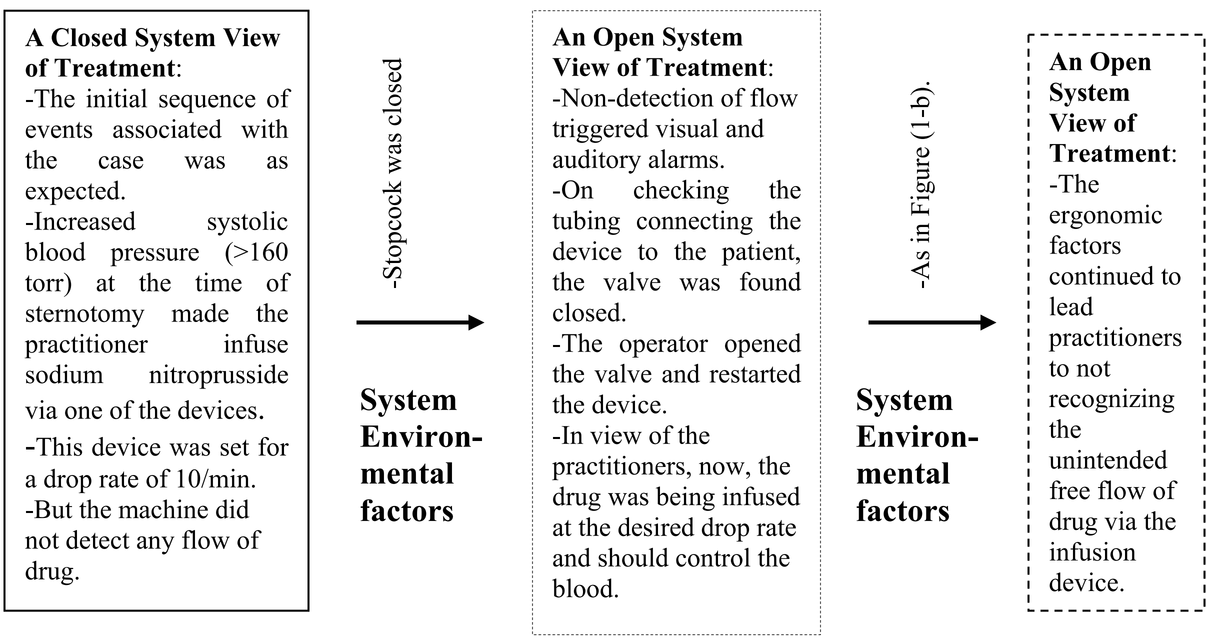


**Figure (1-c): Information recognition error despite the device alarm for the first time leading to loss of Information Origination Integrity**

**A closed System View of Treatment**:
-Consequent to the first alarm, the operator opened the valve and restarted the device.
-In view of the practitioners, now, the drug was being infused at the desired drop rate and should control the blood.

The controller alarmed again, with the same message (as the first time), which indicated either that no drug is delivered or that the device is turned off.

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**System Environ-mental factors**

**An Open System View of Treatment:**
-However, the reality was different.
-When the stopcock (valve) was opened, free flow of fluid containing drug began. The controller was restarted, but the machine again detected no drops because the flow was wide open and no individual drops were formed.
–As a result, the controller alarmed again, with the same message (as earlier), which indicated that there was no flow. *That is, when fluid flow was wide open, the alarm indicated no flow*.
-On the part of the communication system that the alarm represents, this is **a design error resulting in communication error contributing to incorrect recognition (production) of information. Acting with delay, in this case, this design error led to information origination error**, as when flow in fact was wide open the message delivered was that there is no flow.

**Figure (1-d): Information recognition error despite the device alarm the second time leading to loss of Information Origination Integrity**

**A Closed System View of Treatment**:
-In spite of the open system view of the treatment, on account of the system environmental factors as in Figures (1-b), (1-c) and (1-d), the information assumed by the practitioners was that *the drug was being infused at the desired drop rate and should control the blood.*

*DEVELOPMENT OF PROCESSES OVER TIME*
-In reality free flow of the drug was underway.
-Between the opening of the stopcock and the generation of the second time error message, sufficient drug was delivered to reduce the blood pressure.

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**System Enviro-nmental factors**

**An Open System View of Treatment**:
-The operator saw (recognized) the reduced blood pressure
-Concluded drug not required, when in fact "free" flow is what was not required
-Pushed device button marked "off."
-For the practitioners, the device was "off", therefore not delivering any drug, and therefore not a plausible cause of the hypotension.

*-Device was powered down, but the flow of drug continued.*
-Fall in blood pressure transformed hypertension into the problem of hypotension.
-Hypotension was a critical threat to the patient.
-For practitioners, this created TIME PRESSURE.

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**System Enviro-nmental factors**

**An Open System View of Treatment:**
-Time pressure did not allow committing information processing resources to recognize that the device was administering free flow of drug and as a result the said information recognition error continued.

**Figure (1-e): Due to TIME PRESSURE, information recognition error despite the device alarm the second time leading to loss of Information Origination Integrity**

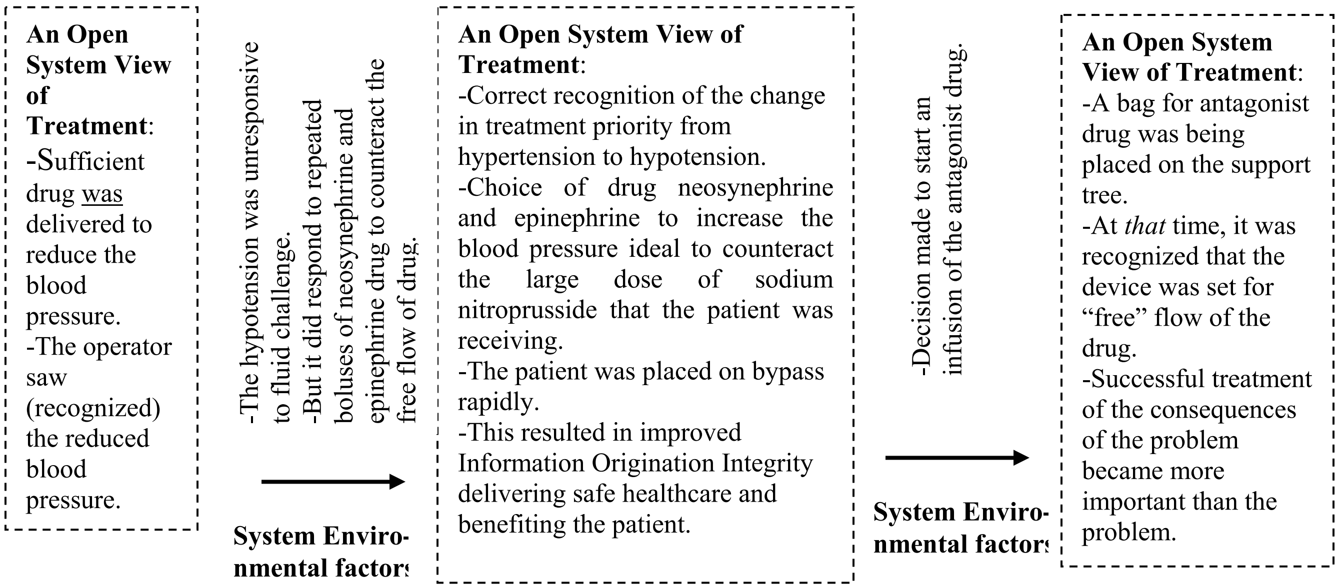


**Figure (1-f): Correct information recognition resulting in improved Information Origination Integrity leading to delivery effective healthcare**

## 6. Emerging insight: Controlling correct information recognition, i.e. controlling Information Recognition Integrity for Effective System Management

In Section (3) it is pointed out "*when something in the environment is found anomalous (deviating from what is standard, i.e., integrity deviation), it necessitates information recognition, i.e., information origination in respect of that thing*." Environment can be broadly divided into two categories; namely, (i) organizational environment and (ii) operational environment [3,6,7].

### 6.1 Organizational Environment

This covers physical and functional resources available to deal with the system problems (failures). These resources are based on closed system view of the system and include informational resource, which supports pre-determined information decisions identified exogenous to the problem situation. Accordingly, organizational environment is also termed as direct or concrete environment. Anomaly in the organizational environment is modeled as a statistical noise in these system resources. Descriptively, presence of noise is the issue of inexactness from the pre-determined value.

### 6.2 Operational Environment

Anomalies can also be due to *distortion* in system resources, which in turn have implications of *incorrect* (as opposed to inexact) production of information. Such anomalies are to be observed in complex and constantly changing environment, which calls for open system view of the system problem. This is the basis for defining an operational environment, which comprises informational resources to deal with system problems (failures and opportunities). These (informational) resources are:

(i) Knowledge factors – situation specific local market factors that can be drawn on when solving a given problem situation.

(ii) Strategic factors – the trade-off between goals that conflict during decision- making under uncertainty, risk, and limited information recognition resource (e.g., criticality of demand, time pressure, opportunity costs).

(iii) Information recognition dynamics (models) – factors that govern the control of information recognition as problem situations evolve (progress) in time.

As can be seen, this informational resource supports flexible information decisions, which are determined endogenous to the problem situation. From this angle, the operational environment can be viewed as an abstract or indirect environment

**6.3 Environment Anomalies – A Comprehensive View**

The term "system" here represents system, its sub-systems and their components. Organizational and operational environments are both internal as well as external to the system. Implications of system failures under anomalies in operational environment are the consequences of incorrect origination (production) of information. Whether due to distortion or due to noise, information is rendered incorrect. *Therefore, consequences of incorrect production of information comprise implications of anomalies in both categories of environments, namely, operational and organizational.* In other words, operational environment is the higher order or derivative of organizational environment and is supported by the organization's physical and functional resources for its existence. For effective and efficient system performance the requirement is to keep increase in the entropy of the system's operational environment to the minimum. In complex and changing environment, this requires that, given the conflicting goals, information on local market factors is recognized correctly, i.e., with integrity.

**6.4 Controlling correct information recognition – The significance**

In the exemplar incident, *that* day in *that* particular situation, a chain of multiple events came together. These were: (i) initial procedural error (slip) in assembling one of the infusion controller device; (ii) ergonomic factor errors in device installation/operation, namely, (a) the drip chamber being obscured by the machine's sensor, making visual inspection difficult, (b) presence of an aluminum shield around the fluid bag, hiding its decreasing size, and (c) presence of multiple devices, making it difficult to trace the tubing pathways; (iii) closed stopcock in the tubing, whose unearthing inadvertently made practitioners less concerned about other possibilities (e.g., device being set for "free" flow) while investigating why blood pressure was so falling; and (iv) build up of time pressure in the wake of critical situation created by the case transforming into that of hypotension.

As explained through Figures (1-b) to (1-e), while the above chain of events points to the patient condition becoming progressively critical due to the continuous loss of Information Recognition Integrity, subsequently, there was the correct recognition of information in respect of the identification of the antagonist drug. This improvement in the Information Recognition Integrity led to the patient recovery.

From above, it follows when <u>something</u> is anomalous in the environment, i.e., when there is an ***unexpected change*** in the environment, it *necessitates* information recognition, i.e., information origination in respect of <u>that</u> thing. In the exemplary incident, it is by controlling (i.e., improving) the Information Recognition Integrity that the coronary artery bypass graft procedure rendered safe and reliable healthcare service for *that* patient. This delivered competitive advantage to the treatment's internal customers and to the healthcare enterprise as a whole. This presents Information Integrity (I*I) of information recognition, i.e. *correctness* requirement of information recognition, as a controlling factor for adding value to healthcare management.

## 7. Enterprise Resource Requirements for Information Recognition Process

Recognizing the need for controlling I*I of information recognition brings in the question of enterprise resource requirements for information recognition. What are these resource requirements? These are [3,6,7]:

- ***Knowledge factors***

a. Development of models that decision-making can use for understanding technological, physical, and physiological processes.
b. Development of processes to reveal gaps between the decision-making process view of the system/sub-system/component and the actual design.
c. Complete feedback to the decision-making process on system/sub-system/component detailing internal relationships between its different modes.
d. Development of directory of <u>situation-relevant</u> knowledge (subtle information patterns inclusive) that is accessible (particularly to reduce time pressure) under the conditions in which the decision-making task is <u>actually</u> performed.

- ***Strategic factors***

e. Processes to identify interacting goals (multiple criteria and many factors) by selecting or constructing the means to satisfy all sufficiently. These should result in developing operable goals for considering immediate implementation.
    a. These processes are invariably missed in the traditional decision-making.

- ***Information Recognition Dynamics***

    o <u>Recognizing changing situations</u>

f. Processes to track in time the shifting patterns of interactions between different sub-problems.

    o <u>Revising situation assessments</u>

g. Processes to see persistence over time with certain information.
h. Development of cues, available or potentially available to the decision-making processes that could have started the revision processes if observed and interpreted properly.
   **Note**: Knowledge factor at (d) above is expected to be of significant value in information recognition.

## 8. A Systems Approach to I*I of Information Origination Process

In view of an open system view of a healthcare process, it (healthcare process) can be modeled as an integral to a closed loop healthcare information and control system. We designate this information system as healthcare process *IS* view. I*I research shows that this *IS* is a multistage decision process. These decision stages span a spectrum: <u>from</u> *obtaining* 'many factors' & 'multiple criteria' defining the problem situation complexity <u>to</u> the problem *information recognition*, i.e., operable goal setting <u>to</u> *culling out* relevant interdependent information variables <u>to</u> *dynamic structure* characterization <u>to</u> undertaking *customized* planning and design for generating alternatives for evaluation and final selection of *flexible information decision* for control implementation. This is a continuous individual information origination and processing situation in the presence of uncertainty and is termed information origination under uncertainty. What is significant is each of the decision stages is also an information origination situation in the presence of uncertainty [6,7,8].

This forces attention to the information origination situation and its relation with the information recognition process requirement.

**8.1 Information Recognition: A Central Feature of Information Origination Process**

Individual elements of an information origination process are [5,6,7]:

Element 1: Observation of the Real World Events;
Element 2: Verification of Problem Area Data/Information Observed;
Element 3: Problem Information Recognition or Operable Goal Setting
Element 4: Prediction of Future States
Element 5: Coordination of information origination activities with reference to:

- Attending to information
- Prioritization of problems and activities
- Selection of flexible information decision
- Control implementation
- Reevaluation

Element 6: Selection of Flexible Information Decision and Control Scheduling
Element 7: Input-Process-Output Implementation
Element 8: Reevaluation
Element 9: Information origination resource management

From above it becomes clear that information recognition is one (and not the only element) in the chain of elements that goes to define each of the decision stages under the information origination process that the healthcare *IS* is. In other words, for controlling the information origination, it (information recognition) is not the only critical element that need be controlled. However, the *key* thesis here is that the changing environment necessarily presents complex problem solving situations. Unlike simple laboratory worlds with the "best" choice, real complex systems intrinsically contain *conflicts that must be resolved*. This requires elucidating the relevant goals, the interactions between these goals and the factors that influence criterion setting on how to make trade-offs in particular situations. ***This makes problem information recognition a central feature of information origination process model that applies to complex dynamic worlds***. It is the implementation of effective information recognition process that goes to facilitate a working model of an open system view of any real world system under consideration.

The role of interactions between conflicting goals and factors that influence the situation specific trade-offs is often missed in traditional decision-making models, which are designed for static environments. As a result, it is easy for organizations to produce what appear to be solutions that in fact exacerbate conflict between goals rather than helping organizations deliver value added products. In part, this occurs because it is difficult for many organizations (particularly in regulated industries) to admit that goal conflicts and trade-off decisions arise.

In other words, it is *only* by committing internal and external system resources for correct recognition of information that an effective and economic information origination can be ensured. In the absence of this resource commitment, the information origination process is likely to be rendered ballistic and is likely to put whole attention after a predetermined information pattern. It may seem easier to pursue, cost less in the immediate term and give a false sense of having taken analytical steps to originate information, but in reality it does not add value to the product delivered and in the long run increases supply chain costs.

**8.2 Information Origination Integrity – A Systems View**

Sections (2) and (3) analyzed how in the exemplar incident the loss in healthcare goal was due to loss of healthcare Information Origination Integrity. Against this, Section (4) showed how benefit was obtained to the healthcare goal by improvement of healthcare Information Origination Integrity. This presents I*I of information origination process, i.e. of the healthcare process *IS* view, as a critical factor for delivering safe healthcare. Further, Section (8.1) observed that information recognition is a central feature of the information origination process model that applies to complex dynamic worlds, though it is not the only element of the information origination process.

This leads to a systems view of Information Origination Integrity, which in addition to Information Recognition Integrity, can now be seen to comprise Observation Integrity, Verification Integrity, Prediction (Forecasting) Integrity, Coordination (Monitoring) Integrity, Flexible Information Decision Integrity, Control Integrity, Implementation Integrity, and Reevaluation Integrity [6,9]. It is when these integrity requirements are met, that I*I processing initiatives in respect of healthcare process *IS* view as identified in white paper entitled "Making A Case for I*I in Healthcare – Example 1" can be met [5,6,7]. This further adds to the visualization of the vast I*I Technology development market space in the healthcare service domain.

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