Decision Making Processes for a Patient with Cardiac Pacemaker Admitted to the Accident and Emergency Undergoing Magnetic Resonance Imaging – A Case Study

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This case study aims to apply the processes of decision-making for magnetic resonance imaging (MRI) as a diagnostic examination for a patient with cardiac pacemaker admitted to a private hospital in the capital of Indonesia. It also aims to examine and evaluate the case of a 53-year-old mother who had a heart abnormality that has a pacemaker for one year and was diagnosed to do an MRI examination because of a suspected tumor on the wrist area.

The three basic models of decision-making — the descriptive, prescriptive and normative — were applied. The prescriptive used the information processing theory, while the normative used decision trees as decision options and lastly, the descriptive used intuition and pattern recognition.

Dominantly, the prescriptive model for decision-making is more appropriate for this case. The descriptive decision-making model, using intuition however, helped in supporting the intuitive hypothesis. Lastly, the normative model of decision-making played an important role but was not likely effective.

Key words: Decision-making processes; case study; MRI with pacemaker; A&E

This case study aims to apply the processes of decision making for magnetic resonance imaging (MRI) as a diagnostic examination for a patient with cardiac pacemaker admitted to a private hospital in the capital of Indonesia. It also aims to examine and evaluate the case of a 53-year-old mother who has a heart abnormality with pacemaker for one year and should be doing an MRI examination because of a suspected tumor on the wrist area.

BACKGROUND OF THE STUDY

An MRI is generally contraindicated for patients with pacemaker or implantable cardiac defibrillator (ICD), because of the risk of life-threatening interference with the device (Bovenschulte *et al.* 2012). However, compared

with computerized tomography scanning and ultrasonography, only the modalities of an MRI is capable to show the soft tissues and joint fluids hence can easily see abnormalities (Kartawiguna 2014). This is because MRI images can capture process-based location and the atomic number of cells (Kartawiguna 2014).

Based on surveys which have been reported, more than 650 000 patients every year are installing a new pacemaker implantation worldwide (*Figure 1*). Where it contained 50% to 75% of these patients, it developed indications for MRI during their devices and showed that every year, approximately 200 000 patients with pacemakers or ICDs, MRI was rejected (Roguin *et al.* 2008).

Figure 1. Number of annual MRI scans and of newly implanted ICDs (Roguin et al. 2008).

There are potential effects of MRI to cardiac pacemakers and ICDs that were considered to be absolutely contraindicated due to the following potential issues (Shellock et al. 1999): (1) Movement and/or vibration of the pulse generator or lead(s); (2) Temporary or permanent modification of the function (i.e. damage) of the device; (3) Inappropriate sensing, triggering, or activation of the device; (4) Excessive heating of the leads; (5) Induced currents in the leads and (6) Electromagnetic interference.

In Indonesia, with the increasing prevalence of implantable devices and the increasing utility and availability of MRIs, there are many occasions where there is a great medical need to perform MRI in patients with an ICD and pacemakers. As a result, these have led to the development of the guidelines for scanning patients with cardiac pacemakers / ICDs (FDA Recommendation).

THE CASE

A 53-year-old mother admitted to the accident and emergency (A&E) department with great pain and swelling in the wrist area

without trauma cases. The author and the A&E department physician-in-charge intuitively suspected an abscess. Radiologic X-ray examination of the wrist joint was conducted. However, the results were not clear showed in the X-ray. After analyzing the medical history of the patient, it was found that the patient had installed a pacemaker in her heart because of an arrhythmia a year ago.

Clinical specialists concerning heart and pacemakers say that MRI and other investigations for purposes of advanced diagnostic examination might be contraindicated. However, A&E physician-in-charge instructed the author (as the radiologist), that soft tissues and joint fluids from the patient's wrist needed to be visualized using an MRI.

The author identified possibilities of giving options by looking at the history and the operation techniques done on the patient. The author also explained to the patient the American Society for Testing and Materials International (ASTM) recommends grouping of pacemaker patients into three categories, which are: Safe magnetic resonance (MR), the

MR compatible / MR and the MR conditional prohibited / MR unsafe (ASTM International 2003).

Having investigated by interview that the patient was using Medtronic pacemaker with a new generation of materials, the MR categorised as 'conditional' was hence advised by the hospital as a norm for doing an alternative to MRIs. *Figure 2* shows the decision tree as the decision option for the patient. These options are used for patients with cardiac pacemaker who will undergo MRI (ASTM International 2003).

The relatives' decision (Say & Thomson 2003) are also important to be considered, therefore the A&E physician-in-charge presents probabilities shown in *Figure 2*, to the relatives during the discussion.

The patient was encouraged by the A&E physician-in-charge and clinical experts to take the MRI conditionally. According to clinical guidelines, there are altered physiologies to be considered when patients are brought into the radiology departments that have pacemakers or ICDs. Primarily it may lead to radiation frequency (RF) interference, shifting location of pacemakers, and thermal effect (Shellock *et al.* 1999).

However, in the category of the MRI compatible/MR conditional pacemakers, these could contain risks that could be fatal for the patient. The development and implementation of

cardiac MR conditional devices would continue to require the expertise and collaboration of multiple disciplines and would need to prove safe, effective, and cost effective patient care.

Figure 3 explains the altered physiology of patients with pacemakers undergoing MRIs and analyzes the hidden effects after doing the MRI examination.

A risk-benefit ratio must be established before the MRI examination procedure is carried out (University of California San Francisco Guidelines 2015).

Upon Entering the Radiology Unit

The author intuitively perceived the main risks of MRIs that was conceived of a large magnetic force with magnetic attraction that was extremely large, in which attractive force is the potential to affect the projectile and change the location of the patient's pacemaker (Brown & Semelka 2003).

The author adjusted the field strength to 1.5 tesla (Shellock *et al.* 2004).

Figure 4 shows the resonant frequency in megahertz (MHz) as the formula that was used by the author, referred to as *Larmor Frequency* (Kartawiguna 2015).

If it uses magnetic field strength of 1.5 tesla, then the value of the RF must only be at 63.9 MHz (Kartawiguna 2015). The greater the RF

Figure 2. The decision tree divided into probabilities.

Figure 3. Altered physiologies of patients with pacemakers undergoing conditional MRIs.

$$\omega_0 = \gamma B_0$$

ω_0 is Larmor frequency (MHz tesla)
 γ is gyromagnetic constant (MHz tesla⁻¹)
 B_0 is magnetic field strength (Tesla)

Figure 4. Larmor frequency.

used will give a bad effect on the patient with pacemaker (Götte *et al.* 2010).

However, by using a magnetic field that is less than 1.5 tesla, will require a longer scanning time (Roguin *et al.* 2004). This is because the scanning time is inversely proportional to the resonant frequency (Brown & Semelka 2003). The author must explain to the patient that she

would need to be scanned more than 30 min inside the MRI scanning device.

The procedural management of MRI for patients with pacemakers or ICDs is primarily divided into (1) protocols and examination procedure; (2) procedural management setting and measures, and (3) planning and conduct of procedures.

Performing these skills found on Table 1 was important since the heating effect occurred during MRI. The energy heats the RF deposits on body tissues (Bovenschulte *et al.* 2012). This results in warming of the endo-/myocardium that may lead to edema formation or even scarring, which in turn can result in alteration of the pacing thresholds (Bovenschulte *et al.* 2012). In addition, the Specific Absorption Rate (SAR) is a reference to the body's ability to neutralize energy (Bovenschulte *et al.* 2012). The author was needed to measure the energy arising from the MRI, and on the type and position of the electrode of the pacemaker.

The increase in temperature approached those used in thermos-ablative procedures, so the potential for harm was considerable; this can be expressed, for instance, in alterations of the pacing threshold (Nazarian *et al.* 2011). The amount of the SAR recommended

a <2.0 kg to an average SAR of <3.2 kg (Bovenschulte *et al.* 2012).

The MRI scan was conducted by an attending radiologist, and monitored by a cardiologist and an electro-physiologist. The patient was also monitored by the author continuously during the MRI (e.g. blood pressure, pulse rate, oxygen saturation, and ECG).

During the examination, the patient was monitored using electrocardiography and pulse oximetry (Nazarian *et al.* 2011). The author also maintained visual and verbal contact on the patient throughout the MRI procedure. *Figure 5* shows the electrocardiographic result with evidence of a captured pacemaker.

The author also instructed the patient to verbally communicate in case of any

Table 1. Procedural management (The position paper of the European Society of Cardiology 2008)

Procedural management of MRI in patient with a pacemakers or ICD		
MRI protocols and examination procedure	PM/ICD settings and measures	Planning and conduct of procedure
<ul style="list-style-type: none"> • Restrict scanner field strength to ≤ 1.5 T • Keep SAR of sequences used as low as possible, no SAR > 2 W/Kg • Plan examination precisely in advances as possible • If possible, do not use surface coils 	<ul style="list-style-type: none"> • Perform MRI no less than 4–8 weeks after implantation • Inspect device thoroughly before and after MRI • Continue monitoring after MRI until completion of reprogramming and testing (threshold values of sensing and pacing) • Switch PM to “off” during MRI (sensing only) or to “output” below the pacing threshold • ICD treatment off • Non-PM-dependent patients on asynchronous mode • Check ICD/PM parameters (pacing threshold etc.) after 1 month and 3 months 	<ul style="list-style-type: none"> • Perform the examination at a well equipped centre with experienced staff • Obtain cardiological assessment of PM (non) dependence, if patient is PM dependent, consider re-evaluating the indications • Radiologist and cardiologist should be present during the examination, with continuous monitoring (ECG, blood pressure, pulse oximetry) • Programming of the PM/ICD in the MRI suite should be possible • A defibrillator with PM capability should be available in the MRI suite

complications that might arise such as headache, nausea and/or vomiting or to alert the MR system's "push-button" for any unusual heart sensations or palpitations.

As a safety measure, the author also prepared advanced cardiopulmonary resuscitation equipment along the MRI hallway, along with an external cardioverter or defibrillator and the programmer of the pacing device (Nazarian *et al.* 2011).

After the scan, a systematic questionnaire was provided to the patient to inquire regarding pain, sensation of movement of the pacemaker device, heat felt on the chest, or any other discomfort. In addition, the duration of the MRI was noted and the A&E physician-in-charge assessed the patient of any untoward signs and symptoms.

After the examination an electro-physiologists checked the pacemaker performance. The result showed no changes on the pacemaker device, but the patient still must be followed-up within 1 to 3 months.

The author however, was also aware about the procedural management as a clinical guideline for the patient undergoing MRI comprising three basic components:

- (1) The technical requirements for the MR scanner and the selection and planning of examination sequences;
- (2) The technical handling of the pacemaker device before, during, and after examination; and

- (3) The basic planning and execution of the examination, taking all appropriate (emergency) precautions to minimize the risk for the patient.

METHODOLOGY

This section examines and evaluates how the three basic models of decision-making — the descriptive, prescriptive and normative (Table 2) — were applied.

Prescriptive Decision-making Model

Information processing theory. Its characteristic uses framework or information and facilitating more effective decision making as its advantage (Bell *et al.* 1995; Harrison 1996).

The information processing theory (IPT) that the author used was the procedural management of MRI in patient with a pacemakers found on Table 1. The procedural management started with technical requirements for the MR scanner, selection and planning of examination sequences and ended with technical handling of the pacemaker device before, during, and after examination.

Step One: Cue Acquisition

Upon admission to the A&E department, the patient was experiencing pain and swelling in the wrist. These were the cues that led to the instigation of having a regular X-ray of the wrist. However, another cue was found on the X-ray results that the wrist did not have any

Figure 5. Patient electrocardiographic result with evidence of a captured pacemaker.

Table 2. Summary of three decision-making models (Shaban 2005; Thompson & Dowding 2002; Tanner *et al.* 1987; Offredy 1998; Dioso 2015)

Normative model	
Characteristics	Rational, logical, scientific, evidence-based decisions.
Information sources	Statistical analysis of large-scale experimental and survey research which is representative of a target population where the findings can be applied.
Examples	Decision trees as decision options.
Advantages	Enable decision-makers to predict and explain the outcomes of decisions. Minimize judgment errors from “base rate neglect”.
Prescriptive model	
Characteristics	Frameworks or guidelines designed to enhance specific decision tasks.
Information sources	Principles and findings of previous scientific research (associated with normative models).
Examples	Information Processing Theory.
Advantage	Facilitating more effective decision-making.
Descriptive model	
Characteristics	Understanding how individuals make judgments and decisions focusing on the actual conditions, contexts, ecologies, and environments in which they are made.
Information sources	Observation, description and analysis of how decisions are made by managers and professionals in relation to their day-to-day responsibilities.
Examples	Intuition.
Advantage	Adequacy in supporting assumptions made about decision-making processes with relevant examples from a suitable period of observation.

fractures or dislocations. That was why an MRI was hypothesized to be indicated.

Step Two: Hypothesis Generation

It was hypothesized that patients with pacemakers would not survive computerized tomography scanning; therefore, in order to visualize the soft tissues on the tumor found in her arm, an MRI was more likely to be indicated. It was also hypothesized that the patient would survive the MRI if precautions would be done using clinical guidelines.

The clinical guideline of the European Society of Cardiology (2008), primarily proposes classification of pacemakers and ICDs into three categories before conducting an

MRI: non-pacemaker-dependent patients (low risk); ICD patients (high risk); and pacemaker-dependent patients (extremely high risk) (Table 3). The patient was classified as low risk.

Therefore, it was hypothesized that in order to survive the MRI, an external defibrillator should be available while conducting the procedure (Nazarian *et al.* 2011).

Another precaution was also hypothesized that in order to survive an MRI an RF wave exposure must be lesser than 1.5 tesla (Bovenschulte *et al.* 2012). This is because an RF takes place repeatedly during an MRI examination that collects enough echo signals to be processed into image data (Bovenschulte *et al.* 2012). In accordance with the Larmor law,

where Larmor frequency will be affected by the strength of the static magnetic field, the greater the strength of MRI is used, the greater the RF wave is released thereby cooking the pacemaker and its battery (Bovenshulte *et al.* 2012). In addition, it was hypothesized that an RF waves were emitted that would interfere with the signal transmission process of a pacemaker thus led to bradyarrhythmic or tachyarrhythmic.

Step Three: Interpretation of Cues

The interpreted electrocardiographic result (*Figure 5*) shows that the patient was positive to have a good functioning pacemaker and was recommended to have an MRI. It was also particularly important for the author to ponder how urgently MRI was indicated and whether there were feasible diagnostic alternatives. Other imaging procedures safer for patient with pacemaker such as ultrasonograms has been considered, but only MRI is more specific that can show soft tissue abnormalities of the patient's wrist (Bushberg *et al.* 2002).

Step Four: Hypothesis Evaluation

It was evaluated that there was a soft tissue tumor found on the wrist of the patient. In this step, it was also evaluated that the patient with cardiac pacemaker was made safe from magnetism. There are three factors relevant for the problematic interactions with pacemakers/

ICDs and their electrodes: the static magnetic field (mechanical effects), the transmitted thermal effects, and the changing magnetic gradients in spatial encoding (induction effects) (Henning *et al.* 2012). The proportion of magnetic metals in devices and electrodes of pacemakers are limited, however, not great enough to cause displacement of either device or electrode, that is why MRI is recommended (Roguin *et al.* 2004).

The pacemaker electrode leads function as an antenna, in which energy generated by variable magnetic fields is conducted to the adjacent tissue in the form of heat (Henning *et al.* 2012). This results in warming of the endo-/myocardium that may lead to edema formation or even scarring, which in turn can result in alteration of the pacing thresholds (Sommer T, Naehle CP, Yang A, *et al.* 2006).

The pacemaker device may be directly affected by electromagnetic interference (Shinbane *et al.* 2011). One factor is the activity of the reed switch. The standard parameters may not always suffice for effective stimulation in patients who need high initial energy (Shinbane *et al.* 2011). The main dangers are thus asystole from inhibition of pacing and induction of tachycardia by inadequate asynchronous pacing (Gimbel 2009). *Figure 6* shows the ECG result from patient after MRI examination.

Table 3. Classification of patients according to the risk involved in performing MRI, when no other diagnostic procedure is indicated (The European Society of Cardiology 2008).

Population risk groups		
Group 1 : Extremely High Risk	Pacemaker-dependent patients	Alternative means of cardiac stimulation (transcutaneous electrodes, temporary sensors) should be available
Group 2 : High Risk	ICD patients (non-pacemaker-dependent)	External defibrillation apparatus should be available and emergency pacemaker operation should be done
Group 3 : Low risk	Non-pacemaker-dependent patients	External defibrillation apparatus should be available

Normative Decision-making Model

Patients' relatives were presented with options in a form of decision trees (Say & Thomson 2003). The decision tree found in *Figure 2* was used for this case based on the clinical guidelines in outlining options. However, the physicians still instigated that MRI be advised because the prescriptive decision-making process was the norm that is always done in the A&E.

Descriptive Decision-making Model

Intuitively, as soon as the electrocardiographic results were released, the collaborating health-care professionals descriptively decided that the patient must require other investigations for purposes of advanced diagnostics. Physicians are required to see and analyze the picture of the soft tissue and joint fluid from the patient's wrist.

In a descriptive decision-making, intuition (Offredy & Meerabeau 2005) enumerates probabilities during a discussion. Probabilities are easier to use when collaborating with other experts to intuitively enumerate tasks to measure clinical reasoning (McAllister *et al.* 2009). In addition to Brien *et al.* (2011) and Benner and Tanner's (1987) study on how to trust an intuition, Hams (2000) also said that during discussions with the relatives and the clinical experts, patterns of previously experienced events must be intuitively considered in order to validate an intuition. Banning (2007) supported

this method of decision-making as a role of learning from experiences.

Intuitions are done descriptively according to Banning (2007) by starting with an intuitive hypothesis and perception. Thereby X-ray was chosen at an early stage of consultation but from the X-ray result it was not visible suspicion disorders suffered by patients.

It is usually during the late stage of consultation where intuitive hypothesis generation is trusted (Dioso 2015). That is why the patient was decided to undergoing MRIs.

Banning (2007) said that this process of decision-making, as an intuitive perception is also done by recognizing patterns from past experiences. *Figure 7* illustrates the process of trusting an intuition.

DISCUSSION

The prescriptive decision-making model was dominantly used in this case. The patient acquired the cues but the intuition also supported the IPT that the patient could be safe before, during and after an MRI. However, normative decision-making model was not completely used autonomously by the patient.

The patients are the key decision-makers (Lomas *et al.* 1989). However, if the patient was not completely knowledgeable of the possible disadvantages of an intervention, then

Figure 6. The ECG Result from the patient shows a regular rhythmic capture of the pacemaker.

it is justified that the patient takes advices from healthcare experts (Lomas *et al.* 1989; Offredy & Meerabeau 2005).

In this case study, the patient had chances to choose but it was also seen that there was no other radiologic diagnostic examination that might visualize the abscess intuitively hypothesized that it was found on the wrist of the patient.

RECOMMENDATIONS

MRI of PM/ICD places high demands on both personnel and apparatus, and should thus preferably be performed at well-equipped centres with experienced staff (FDA Recommendation 2015).

It is recommended that the patient with a pacemaker or ICDs should be subjected to MRI only when there is no alternative accurate radiologic diagnostic examination (UCSF Guideline 2015).

Recommendations for static magnetic field devices however must use the static magnetic field 1.5 to 3 tesla, which corresponds to 30 000 – 60 000 times the strength of earth's magnetic field (Shinbane *et al.* 2011). MRI scanners are typically superconducting, thus, they were always attracting ferromagnetic object into the scanner. That is why the devices should be

non-ferromagnetic or weakly ferromagnetic (most are) because it is the lowest field strength available to minimize ferromagnetic risk (Roguin *et al.* 2004).

Recommendations based on material, non-ferromagnetic 'passive' implant (e.g. titanium, titanium alloy, nitinol) MRI should be used immediately after implantation or six weeks after implantation (Nazarian *et al.* 2011).

Recommendation based of the procedural management as a clinical guideline for patient undergoing MRI comprises: (1) The technical requirements for the MR scanner and the selection and planning of examination sequences; (2) The technical handling of the pacemaker before, during, and after examination, and (3) The basic planning and execution of the examination, taking all appropriate (emergency) precautions to minimize the risk for patient safety.

CONCLUSION

It is therefore concluded, that IPT used clinical guidelines in order to decide that MRI was the best option for the patient. Dominantly, the prescriptive model for decision-making was more appropriate for this case. The descriptive decision-making model however, helped in supporting the intuitive hypothesis that there was an abscess in the patient's wrist. Therefore, intuition made the decision-making easier.

Figure 7. How to use an intuition (Dioso 2015).

Lastly, the normative model of decision-making played an important role but was not likely effective since the patient was still relying on the physician's advice.

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