2013 International Nuclear Atlantic Conference - INAC 2013
Recife, PE, Brazil, November 24-29, 2013
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
ISBN: **978-85-99141-05-2**

DECISION MAKING IN BRAZIL AND EMERGING TECHNOLOGIES: THE CASE OF 18F-FDG

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ABSTRACT

The article recalls the history of the development of Fluor FDG in Brazil. Importart facts that impacted this development and how this technology evolved considering a time span of more then ten years, starting from 1996 is presented in this paper. Five decisions, taken between 2004 and 2005, were selected and analyzed from the perspective of knowledge that a key decision maker has developed around the main elements of a decision - problem, objectives, alternatives, consequences, risks approach and linked decisions. Contextual aspects that influenced these decisions, such as the evolution of the technology efficiency, installation of new equipment in hospitals and the consequences associated with these decisions, such as daily production capacity, distance service and numbers of attended clients are part of this study. In conclusion, this case shows that experienced decision makers can make quality decisions when they are equipped with the appropriate information, align the relevant decisions taken over time, know how to use the right tactics at the right time and with all participants in decision making. Experienced decision makers identify opportunities where there seems to be problems, review the current strategies and visualize new strategies, prepare themselves adequately to deal with the uncertainties.

1. INTRODUCTION

Studies involving the processes of relevant decision making under uncertainty environments in R & D in Public Research Institutes in Brazil are not common - in the nuclear sector, even more uncommon. Within this context, we identified one case - the development of the production of 18F-FDG - whose history proved to be a success - in which it was possible to analyze, from the perspective of a key decision maker, how important decisions were taken to facilitate this development. Furthermore, an analysis with a broader perspective of this case, performed eight years after making these important decisions, allowed rescue the history of the development of this important and innovative products for nuclear medicine in Brazil. This study is organized as follows: after this introduction, the second block presents succinctly what is nuclear medicine and what is 18F-FDG, which are its main characteristics, including its production; the third section presents the objectives and the methodology of this research; the fourth block presents the results; the fifth section presents the conclusions and the final block presents the reference of this study.

2. NUCLEAR MEDICINE AND THE FDG RADIOTRACER

Nuclear medicine makes use of the fact that certain radioisotopes emit gamma rays with sufficient energy that they can be detected outside of the body. If these radioisotopes are attached to biologically active molecules, the resulting compounds are called radiopharmaceuticals. They can either localize in certain body tissues or follow a particular biochemical pathway. The use of radionuclides in the physical and biological sciences can be broken down into three general categories; imaging, radiotherapy and radiotracers. Imaging can be further divided into positron emission tomography (PET) and single photon emission computerized tomography (SPECT). All of these uses rely on the fact that radionuclides are used at tracer concentrations. Most of the radiotracers used in vivo should have relatively short half-lives (less than a few hours to at most a few days). There are definite advantages in using short lived radionuclides; for example, there is a low radiation dose associated with each study, serial studies are possible and radioactive waste disposal problems are minimized if not eliminated. The disadvantages are the need for an accelerator nearby or within easy shipping distance for the longer lived species (a few hours), and for rapid chemical procedures, especially for formation of more complex compounds. [1]

2.1 The FDG radiotracer

Fluorodeoxyglucose (18F-FDG) is the most commonly utilized radiotracer in PET to study cell metabolism. FDG is naturally absorbed by cells just like glucose, but cannot be metabolized. The 18F-FDG radiotracer accumulates in cancer cells because of their characteristic high metabolic rate. The 18F emits low energy positrons that are detected by PET scanners.

The synthesis of 18F-FDG requires the use of a cyclotron to produce 18F from 18O enriched water and typically utilizes an 18FDG synthesizer. A limiting factor of 18F-FDG use is the relatively short half-life of 18F (110 minutes[1]) as well as the low yield of 18F-FDG synthesis. The entire process from creation of 18F to synthesis of 18F-FDG to injection into a patient must occur within several hours. This has led to the creation of several automated 18F-FDG synthesizers that utilize kits to aid the process.[2]

2.2 Production

Synthesis of 18F-FDG is an automated computer-controlled radiochemical process that in 2003 was taking approximately 50 minutes to complete.[3]

A commercial 18F-FDG production process could be typically divided in five primary activities: (1) Production of fluoride-18; (2) 18F-FDG synthesis; (3) Quality control and (4) Dispensing and packaging phase. [4]

The majority of the institutions utilizing fluorine-18 for producing radiopharmaceutical synthesis obtain the radionuclide via cyclotron irradiation of appropriate targets. There are a variety of such targets in use, and as a general rule targets system are not equal at different institutions. Often the targets are similar, but designs may reflect the particular characteristics of the accelerator available or even the idiosyncrasies of the individual investigators.[5]

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[1] reviewed by the author

ISBN: 978-85-99141-05-2

Some of the fully automated modules are quite expensive and could cost well above US $100.000. Nonetheless, it does provide an option to establish reliable and regulatory compliant production of radiopharmaceuticals. Using automated synthesis modules is by far the most effective, safe and practical approach to manufacture radiopharmaceuticals.[6]
Increasing clinical demand for 18F-FDG has triggered technological advances in various fields such as accelerator technology, radiochemistry, automated processing modules, detector systems, and imaging software. A typical cyclotron-PET centre nowadays includes a dedicated medical cyclotron together with automated radiochemistry modules and a number of PET or PET-CT units. Daily large scale production of 18F-FDG in the early morning hours for extensive and rapid distribution to medical centres is becoming common practice in several countries. [7]

3. OBJECTIVES AND RESEARCH METHODOLOGY

3.1 General Objectives

- Redeem the story about the early development of the production of 18F-FDG in Brazil

3.2 Specific Objectives

- Map the development of the production of 18F-FDG in Brazil combining technical data, data capacity and the market served with the key decisions that guided this development;
- Report in synthetic terms, the decision making process of key decisions for the development of production of 18F-FDG in Brazil and,
- Analyze the decision making processes of key decisions by characterizing the context of the problem, objectives, alternatives and their consequences, the decision maker risks approach, the decision taken and linked decisions.

3.3 Methodology

This research was conducted in two different periods and with different goals as well. The first period occurred between 2005 and 2006 and analyzed in depth the key decisions made between 2004 and 2005 aimed at developing the production of 18F-FDG in Brazil; the second period ocurred in 2012 when we developed a more comprehensive retrospective of this development.
The early development of the production of 18F-FDG in Brazil occurred in the laboratories of the Nuclear and Energy Research Institute, IPEN. We interviewed a director and two production managers involved in R & D of 18F-FDG. Twelve interviews were conducted with the director and five interviews with production managers. Interviews with director lasted around an hour on average, with situations in which reached almost three hours and were interspersed with periods ranging from weeks and months. The first interviews took place on July 6th, 2005; the last on August 23th, 2006. The interviews with the production managers lasted on average 1 hour each and were used to validate the overall steps of the decision process.
The research conducted in 2012 aimed to survey technical data about the 18F-FDG production. This was done accessing public information available on the Internet.

The results of this research selected information were organized in the form of a table and an info-graphic representation (both are presented in the Results block). The table lists the following information: actors, key decisions, dates, farthest city serviced (name) logistics (airway or roadway) and facilities evolution / important facts. The info-graphic representation included the following historical data: production capacity evolution (daily doses), delivery distance range (km), key decisions, average synthesis efficiency (%), target (ml), total anual production (doses) and clients attended (units).

To analyze the decision making of key decisions of the early F18-FDG production development phase the following work steps were developed:
1. Initial non-structured interviews, in order to identify the decisions to be researched and obtain the background of these decisions (five decisions were selected);
2. Collecting the documents and getting complementary data and/or the information, to confirm, at least in part, what was obtained through the interviews;
3. Semi-structured interviews (application of the script presented in the Appendix 1 for each decision making process – one interview, one decision making focus), in order to identify the elements in each of the five decisions as well as the tactics used throughout the decision-making processes.

For the preparation of the synthesis of decision making the following work steps were developed:
1. After each of the semi-structured interviews, the answers were analysed by the researcher and, in the beginning of the subsequent interview the decision elements and the tactics identified from the previously interview were presented and discussed with to decision maker in order to review and validate them.
2. Narrative reconstruction of the decision processes by focusing only on the tactics actived by the key-decisor and who were involved along de decision process.

Tactics were defined as actions performed by the decision maker in order the move closer to decision. From the literature we selected and operationally defined 55 tactics (see [8] for further details). One may thing these tactics as a tool box an experienced decision maker may have and may selected during the decision process according his ability to use them and according to the problem demanding for a decision.

4. RESULTS

4.1 History of the development of production of 18F-FDG

Table 1 lists, in chronological sequence and related form, the actors, the relevant decisions analyzed in this study, the increase in distance of the cities serviced with 18F-FDG and the important facts that contributed or affected the development of the production of 18F-FDG.
Figure 1 plots the numerical evolution of the development of production of 18F-FDG in terms of technical parameters of the production plant together with information on the location of new plants in Brazil and the relevant decisions taken within the production plant of IPEN.

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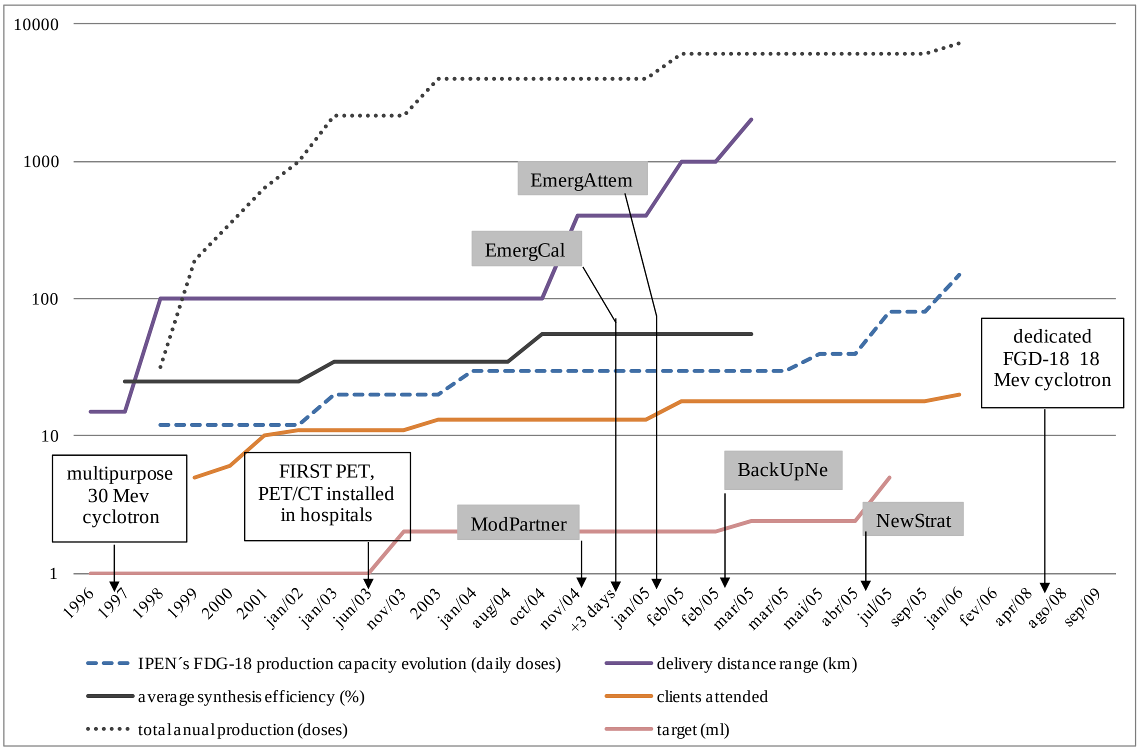
Table 1: Development of the production of 18F-FDG in Brazil: important facts

Actors	decision	dates	farthest city serviced	logistics	facilities evolution - important facts
IPEN - Hospital		1996	São Paulo	roadway	initial productions for two Hospitals (INCOR and H. Cancer) using the CV 28 cyclotron (technology from the seventies)
IPEN		1997			inauguration of the 30 Mev multiproposit IBA cyclotron (planned initially to produce 167 Ga, 201 Ta and 123 I); 1 synthesis module - (IBA 1) with 20-30% of efficency and low reliability; 1 new 1 ml target-port
IPEN, Hospital		1998	Campinas	roadway	FDG-18 initial commercial production; first PET/SPECT system installed in Brazil (Instituto do Coração - INCOR, a public funded Hospital); development of a prototype of the PET/CT system in the EUA
IPEN		1999			beggining of the regular production of the FDG-18
IPEN		2001			1 or 2 maximum FDG-18 production batches per week
IPEN		jan/02			technicians training trip to Belgium: first information concerning a new synthesis with high reliabilility
IPEN - Hospital		jan/03			1 new synthesis module (IBA 2), 30-40% of efficency (Hospital do Cancer - HCan partnership)
Hospital		jun/03			First PET technology system is installed at INCOR; First PET/CT is installed at the Sirio-Libanes Hospital
National Congress		nov/03			proposed constitutional ammendment (PEC 199/2003) that breaks the monopoly of radioisotopes of short half-life (less than two hours)
IEN		2003			FDG-18 regular production initiated
IPEN		jan/04			1 new 2 ml target-port
IPEN - Hospital		aug/04			Sirio-Libanes Hospital (private hospital) asks about the possibility of a second FDG-18 production shift
IPEN	ModPartner	oct/04			1 new synthesis module (GE 1), later evaluations indicated 55% efficiency (the new module substituted the IBA 1), (Intituto do Coração Hospital partnership)
IPEN	EmergCall	nov/04	Rio de Janeiro	airway	emergency call from Rio de Janeiro
IPEN - Clinic	EmergAttem	+3 days			beggining of the attempt to service Rio de Janeiro Clinic 3 days later
IPEN		jan/05			IBA synthesis module performance evaluation publication
IPEN - Clinic		feb/05	Brasilia	airway	first service to a Brasilia Clinic
IPEN - IEN	BackUpNeg	feb/05			the beggining of back up negotiations; (signed approximately 40 days later on with retroactivity effect from the date of the initial discussions)
IPEN - Clinic		mar/05	Salvador	airway	first service to a Salvador Clinic
IPEN		mar/05			beggining of potential clients visits in large cities: Jau, Curitiba and Rio Preto (~400 km distant from São Paulo)
IPEN - IEN		mai/05			initiated regular second FDG-18 production shift (noon) initiated: Tuesday and Thursday; first shift: limited to 4 doses; new 2,4 ml target-port installed
IPEN, CNEN-DPD	NewStrat	abr/05			proposal of a second dedicated cyclotron to CNEN-DPD; new strategy (long distance clients service range) formally decided
IPEN		jul/05			1 new synthesis module (GE 2); 1 new 2,4 ml target-port (substituting the old one)
IPEN		sep/05			GE synthesis module performance evaluation publication
IPEN		jan/06			1 new 5 ml target-port ; old Cyclotron CV 28 disassembled
National Congress		fev/06			approved a constitutional amendment that breaks the monopoly of radioisotopes of short half-life (less than two hours)
CDTN		apr/08			inauguration of the FDG-18 laboratory production based on a 18 Mev GE Cyclotron
IPEN		ago/08			inauguration of a dedicated 18 Mev IBA Cyclotron for the FDG-18 production
CRCN-NE		sep/09			inauguration of a dedicated 18 Mev IBA Cyclotron for the FDG-18 production

Analyzing Table 1, some facts can be highlighted: (1) the rapid introduction of technology in the market: from the first experiments in production IPEN until the commencement of commercial production takes place in just one year; (2) the change of distribution logistics: from roadway to airway in 2004 and the consequent increase in delivery distance from IPEN, located in São Paulo, to Rio de Janeiro - distant 400 km from São Paulo – an emergency service due to a failure of cyclotron located at IEN; (3) initiation of regular supply to 1000 kilometers from one year after the emergency service, (4) dissemination of production plants 18F-FDG: IEN in 2003, Rio de Janeiro, in 2008 CDTN, Belo Horizonte and in 2009 CRCN-NE, Recife; (5) beginning of the discussions about ending the monopoly nuclear for short-live radioisotopes in late 2003 and the approval of it in early 2006.

Figure 1: Development of the production of 18F-FDG in IPEN: evolution



Analyzing Figure 1, other facts call attention: (1) the rapid production escalation: 1999 is the start of regular production; in 2003, the first PET, PET / CT are installed in hospitals and the annual doses leaves the level of 350 doses and rises to about 4000 doses in 2004 and, in 2005, reaches approximately 6000 doses; (2) the rapid evolution of the efficiency of synthesis technology: in 1997 was around 25%, in 2002 rises to 35%, in 2004 rises to 55%; (3) the development of production capacity: in 1998 was 12 daily doses, in 2003, to 20 doses, in 2004, rose to 30 doses, in 2005, passed for 40 doses and, soon after, went to 80 doses and, in 2006, passed for 150 doses.

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4.2 Brief Description of Five Relevant Decisions

The following is a summary of five key decisions that provided the foundation of how the early development of the production of 18F-FDG occurred in Brazil.

4.2.1 Module partnership decision

After a process of investment in technology started in 2002, two years laters, in 2004, it was identified that there was a lack of funds for the purchase of a synthesis module production of 18F-FDG. Two solutions would be attempted, but with unsuccessful result: (1) the transformation of resources allocated to fund basic into resources allocated for equipment and (2) the search of resources from other units of the CNEN. The conventional solution under the Public Service would be the postponement of the investment for the next fiscal year, something that would not meet society at the time and that, too, would not satisfy the decision makers involved in the decision making process. Thus was initiated by a key decision-maker - the director - the search for alternative solutions. The solution - the development partnership - was found based on his experience and was analyzed initially by him based on its pros and cons and by the preview of the consequences arising from the acquisition of equipment through partnerships. Then he evaluated the ethical aspects and risks involved in with the technical team. Next, he made further analyzes, also based in his experiences, and concluded the need to consult a higher instance of IPEN, in case the CNEN.
Whereas the decision would not be without risks, the director chose to share the risks with the participants of the decision making process and, in order, to reduce the risks involved, it was decided that the partnership would be made with a public organization. If there was a need to provide information in the future about the decision, technical and financial analysis would be used to answer any questions about the decision.

4.2.2 Emergency Call Decision

Within the context of investment in the expansion of the production facilities of 18F-FDG, aiming to supply the growing demand for São Paulo and Campinas (the distribution was limited to a radius of 100 km given the short half-life of the product) in November 2004, a client in despair headquartered in Rio de Janeiro contacts by phone the director of the IPEN. In this connection, this client - and that's a doctor - explains the emergency situation that he was facing: due to severe failure in the cyclotron - a key equipment in the production of 18F-FDG - installed in one of the units located in Rio de CNEN January, the clinic was already failing to attend their patients for almost 30 days. In addition there was a growing concern for investors with the technology that was acquired by the clinic to facilitate the diagnostic procedures using 18F-FDG. While the phone call unfolded, the director was developing mentally, what to do to resolve the situation as described bellow.
Given his knowledge of the current production capacity - and that reflected the investments made in order, in the long term, to attend the growing demand in São Paulo and Campinas - there was the perception by the diretor that, in the short term, there would be an opportunity to try the service that customer located in Rio de Janeiro facing an emergency situation. However, Rio de Janeiro is 400 km far from São Paulo, which meant that the existing solution (distribution by roadway) would not be plausible given the half-life of less than 2 hours from 18F-FDG. One would have to develop a whole

new and complex logistics involving airway and it would be necessary to produce three times more to serve patients of the clinic in Rio de Janeiro than to serve the same number of patients in São Paulo. Besides these issues, the director knew he would have to convince his superior and the technical team that they would need to produce more to try to attend this clinic. And, to do this, it also would be necessary to have an agreement with the technical team: if necessary, a second daily production would be made to meet all the demand. At the end of the phone call, facing this situation of uncertainty, the director assumed that he would attempt the emergency supply since there was also a partnership, i.e., there would be no pressure in the case of failure in the service.

4.2.3 Emergency Effort Decision

Due to the problem of lack of 18F-FDG and settlement made with the clinic in Rio de Janeiro, the director contacted his superior at IPEN to check his positioning about this emergency effort. Once identified the concerns of the superior, the next step was to develop the logistics with the support of suppliers and define the technical team characteristics that 18F-FDG would need to be received by the clinic within the technical standards and analyze the technical feasibility supply relationship considering the amount of 18F-FDG to be produced and the number of patients attended for Rio de Janeiro and São Paulo. To get support for the previewed solution, the director sought to make prior contacts with members of the technical team in order to identify their specific needs and preventing that small needs could compromise the development of an entire project. To convince the technical team the director argued that the emergency attempt to service to Rio de Janeiro should not be seen as a problem, but an opportunity to do with the 18F-FDG what was already being done with all other products in the products portfolio of IPEN – operating in a limited scope was not a IPEN´s tradition; an opportunity where the technical team could show their technical competence. Another argument presented was that, if this clinical from Rio de Janeiro were serviced, the credibility of the technology would be threatened.
Once the technical team was convinced, this conviction was used as an argument to convince his superior about the possibility of servicing the clinic in Rio de Janeiro without compromising the service to São Paulo.
In order to minimize the possibility of the production level be below the demand, the director combined with the technical team when necessary - without complaints - a second batch would be produced and get a general commitment around the adopted solution - including some skeptics. Besides, everyone should be aware of the risks ingrained in any programming failure, thus avoiding situations like "I told you this is nonsense." Based on this framework, and three days after the fatidic phone call, the decision to try to meet the clinic's Rio de Janeiro in an emergency was taken and implemented as a consensus among all involved.

4.2.4 Back Up Negotiation Decision

Considering the success of emergency supply to Rio de Janeiro, which had already lasted three months, the director of IPEN realized that other distant locations could be supplied with 18F-FDG produced by IPEN. However, the director observed that no authority of CNEN had official knowledge about this effort. He also realized that continuing to supply the clinics located in Rio de Janeiro on the same informal basis could lead to a misinterpretation (eg, invasion of the market) as well inhibit exploiting the opportunity (eg. to serve a larger market). Thus, the director of IPEN has established

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that, the immediate goal to be achieved would be to seek a formal back up agreement. Alternatives to solve the problem, such as an agreement by phone or by e-mail, were discarded because they devalue the importance of the involved actors and would not help the deployment of a second and dedicated 18F-FDG production line - an underlying interest.

After this phase individual analysis, the director initially consulted his superior of IPEN on the proposed agreement and then, together with the technical teams, decided to propose a formal mutual production back-up agreement between IPEN and IEN.

Parallel to these actions, an aide to one of the directors of CNEN received information about the evolution of the production of 18F-FDG and the need to have a second and dedication production line - the idea was to get the support from the board of CNEN to the proposed agreement back up, but without involving the President of the CNEN in the discussions about the agreement - it was known by the direction of IPEN that this issue wasn't considered a priority by the President of CNEN. In order to convince the actors involved in the signing of the agreement, the following arguments were presented by the director to those directly involved in the agreement: (1) the agreement to back up long distances is something feasible due to the existence of experiences abroad where the product was systematically carried by air and (2) the IEN, in case of failure of its production, could say to their customers that São Paulo would supply to them.

Finally, after obtaining the support for the agreement idea, the production levels that one would cover each other in case of failure of one of the sides needed to be negotiated. Initially the director expected that the agreement would be mutual in terms of the quantity to be produced in case of failure of one side. But the agreement was reached only on asymmetric basis, i.e., quantities to be produced by the IEN to São Paulo would be smaller than the IPEN to Rio de Janeiro. This was accepted due to the differences of the logistics and market size of São Paulo and Rio de Janeiro. The decision process lasted about two months, a period of time longer than originally envisioned by the director.

4.2.5 New Strategy Decision

In Belo Horizonte and Recife, cities in which are also located research units of CNEN, investments were being made in the construction of two new production lines of 18F-FDG. On the other hand, there were clear signs of unmet demand for the radiotracer in Porto Alegre, Curitiba (two Brazilian state capitals distant 1100 and 338 km from São Paulo, respectively) and the distant interior of São Paulo - where there are no research units from CNEN. Moreover, with the growing demand in São Paulo, centralizing the 18F-FDG production in a single plant production, in case of a major failure of the production line, an increasing number of patients would no longer be attended.

There was also a perception by the director - given the rapid evolution of technology abroad - that acting in a "restricted strategy" for two more years (estimated time for construction of a second production line dedicated case was approved) could lead to a significant increase in conflicts between IPEN and the medical community.

Thus, considering the level of production that had been already achieved, the successful experience of attending the Rio de Janeiro clients, and also considering that the medical community would not support a solution that would last two years to be operationalized, the director took the initiative to develop a solution to the potential problem and a strategy to convince internal and external "public" of this solution in order to meet the short term these demands in the Southeast and Southern of Brazil. This solution - based on a four-hour road-airway logistic - involves expanding the geographic range and begin to attend immediately demands restrained without having the second production line installed, but, in parallel, seek external support for construction of the second production line. The challenge would then verify if the top management of IPEN would be willing to agree and implement the new strategy.

If the new strategy was approved, the director of IPEN visualized the need to inform customers about the risks involved - in plain terms, in the short term, only one plant would be available and, in case of supply failure, none of these distant hospital and clinics would be attended.

Internally, the development of the solution to the new strategy involved: (1) the definition of a cautious strategy, i.e., for each city to be attended provide a limited amount of 18F-FDG and the activation of the second production with safety margin of the order of 20 to 30%, and (2) definition of the characteristics of the dedicated production line as well as the amount of investment needed. To convince the technical team, the decision maker had to negotiate and attend the technical conditions presented by the technical team - he also employed metaphors and labels to explain the "new strategy", such as "attack strategy" or "act as the long arm of technology that can go beyond São Paulo". The analysis of the new strategy also involved the use of pros and cons of each alternative and, to confirm the viability of the new strategy, information was sought with other production facilities abroad. It was also assumed that the risk of failure of the installation would be the same for dealing with 30 patients / day and 60 patients / day. The decision by the new strategy also took into consideration that the investment in a new facility - the order of $ 3 million over five years would generate revenues of $ 12 million. In addition, to convince the top management of IPEN, it was argued that the adoption of the new strategy would be used to justify the need for dedicated production line and, therefore, seek to obtain financial resources by the CNEN for this expansion in production capacity.

This new strategy was being built together with the technical team and the hierarchical superior of the director in such a way that at the end of follow-up meetings, the director had reached consensus among participants, although the responsibility for expanding the area geographic performance based on a single installation should be attributed only to top management. Once the consensus os these participants was reached, the next step of the decision process involved the process of persuasion and final approval along with other members of the top management of IPEN.

ISBN: **978-85-99141-05-2**

Table 2: 18F-FDG development: Decision elements of five relevant decisions

Decision Label	ModPartner	EmergCall	EmergEffort	BackUpNeg	NewStrat
Approximate dates	October, 2004	nov/04	nov-04 + 03 dias	21-02-2005 (signature data, the agreement was signed one month later)	(april/2005 – draft of the dedicated secon line prodution)
Context	Presidency from CNEN has other priorities	(1) Production capacity of 30 flasks / day (2 modules from the manufacturer X, Y 1 module manufacturer and one target port of 2 ml) in January 2004 with the prospect of a new port target port of 2.4 ml and 40 flasks production, (2) knowledge of the experiences of air transportation abroad	the same as EmergCall	Is under discussion at top management of IPEN of a cyclotron installation project fullydedicated to the production of 18F-FDG	(1) Threshold of 40 flasks / day achieved, (2) agreement signed up signaling the importance of -up function, (3) studies and visits to potential customers for evaluation of the change of strategy demonstrate feasibility of the new strategy
Problem	(1) Problems with equity investments, (2) lack of resources for the continued expansion of the production plant of 18F-FDG	Breaking of the main equipment of the plant's production IEN, located in Rio de Janeiro. Current paradigm: you can not provide 18F-FDG over 100 km away.	the same as EmergCall	Continuity of failures in the production plant of 18F-FDG of the IEN (January and February), (2) Breaking the hierarchy from CNEN when it was decided to attend the clinic in Rio de Janeiro that was facing difficulties	The performance of IPEN in 18F-FDG in a defensive strategy opposes to historical trajectory actuation in "attack"
Objectives	Obtain financial resources for increased production	(1) Attending investors worried about their investment and meet a queue of more than 30 patients waiting for an exam. (2) Test whether there were logistics that would account for the supply of a radiopharmaceutical 110 minute half-life to more distant regions of 100km from the capital	Ensure the availability of 18F-FDG, ensuring the commitment of staff to overcome potential obstacles	(1) become official support for the IEN and recover the importance of IEN as a partner, (2) support the IEN, not the customer, (3) establishment of mutual asymmetric back up for the difference of the markets served by each Institute; (4) official recognition of IPEN as a back up for the Southeast	(1) does not inhibit / slow the growth in demand for 18F-FDG and (2) avoid the questioning by the CNEN of the new strategy adopted
Alternatives	(1) partnership with public hospitals or (2) not form partnerships	(1) making an effort to try to attend the clinic or (2) do not attend the clinic	the same as EmergCall	(1) do no close a back up agreement; (2) close any informal agreement based on exchange of e-mails and phone calls (3) close a formal back up agreement	(1) we will say to the market that we will do from now, (2) we will say to the market that we will do this since we have one second cyclotron exclusively dedicated to the production of 18F-FDG
Consequences	(ALT1) leave of 35, 35 flasks and go to level of 50; (ALT2) stay at the current level of	(ALT1) possible end of the queue of more than 30 patients and decreased losses on	(ALT1) triple effort to attend a clinic in Rio de Janeiro and pilot testing of new logistics:	(ALT1) goals will not be achieved (ALT 2) informal solution would not help in	(ALT1) higher degree of customers support to the idea of the second production line on the

Decision Label	ModPartner	EmergCall	EmergEffort	BackUpNeg	NewStrat
	production / delaying the growth of investment in technology	investments made by investors and maintaining the credibility of the technology or (ALT2) patients are not attended by the clinic, investors assume the problems related to return on investment and loss credibility of the technology	feasibility analysis (ALT2) impossibility of assessing the viability	enabling the new cyclotron; Board of CNEN would still not be properly involved in the problem; (ALT 3) minimizing the risk of supply interruption; there would be the involvement of the board of CNEN	(ALT 2) lower degree of binding customers to the idea of the second production line of 18F-FDG at IPEN
Risks approach	In case of questioning by audit, use of technical and financial analysis	Clients of clinics and hospitals in emergency in Rio de Janeiro will only be without 18F-FDG if the capital of São Paulo also run out (there will be no preferential treatment)	Entrance of the second production if necessary	The agreement itself aims to reduce risk in the supply of 18F-FDG	(1) request the dispatch of letters from authorities concerned about the situation of IPEN - the letter called for the necessity of having a second production line for 18F-FDG, (2) strategy of caution: minimum attendance (3) if the production line is not operating is not the responsibility of the production team, is a responsibility of top management who took the risk of increasing the number of users based on a single cyclotron (4) document of persuasion by the CNEN for the construction of dedicated production line
Decision	Investment in increasing the capacity of the process now, with support from partners	try to attend	Agreement with the team with the strategy of "let's try to attend"	Close a formal back up agreement	Attending now with the existing production line with the argument that you can not afford this new strategy the current form continuously - this strategy will be bankrolled by time required for the installation of the new cyclotron that is previewed for 1 and 2 years.
Linked decisions	Not identified	Previous: investment decisions for expansion of productive capacity. Following: How to convince the audit, if necessary	Following: activation of the second production if necessary	Previous: Emergency Service successful in RJ; break hierarchy in emergency assistance in RJ. Following: implementation of the second cyclotron at IPEN	Previous: Emergency Service successful in RJ. Following: Using this strategy of attack as justification for power to provide resources (acquisition) of the second cyclotron (dedicated line production) with the government of the State of São Paulo and the Federal Government.

ISBN: **978-85-99141-05-2**

Analyzing Table 1, we see that in each of the five decisions investigated elements - problem, objectives, alternatives, consequences, risks approach, linked decisions - are present in these decision-making processes. Considering the data collection methodology adopted in this research is not possible to state that each of the decision-making processes has been built following a sequence type logic starting with problem recognizing, setting up the goals, searching the alternatives, analyzing the alternatives and then the decision - certainly not as such ex-post analysis may one lead to believe - but, on the other hand, it is possible to conclude that the basics of a quality decision were considered by the key decision maker during the decision making process.

One aspect that call for a special attention is how these decisions were interconnected - previous decisions created or modified the context of the subsequent decision in such a way that a new and coherent strategy finally emerged - the strategy that was initially considered impossible turned into the regular strategy thanks to the vision, insistence and ability of the key decision maker.

4.3 Discussões

The main events and facts that occurred in the development of the production of 18F-FDG in Brazil between 1996 and 2008 were identified in this study. A particularly important period occurred between 2004 and 2005 when five relevant decisions were taken and they came to define the trajectory of this development in the country. Thanks to these five decisions was possible to (1) acquire new more efficient technologies - the efficiency of the modules syntheses of 18F-FDG increased from 35% to 55%, (2) the annual doses production capacity doubled and (3) the distribution initially made by road up to 100 km from the site of production became road-air to cities up to 1000 km distant.

The first decision - ModPartner - is marked by the key decision-maker intention to improve the production technology in the country seeking a solution from a partnership with a hospital to bring a new technology and more efficient earlier than would be made if the usual limited budget rigidities imposed by public resources and timelines. The second - EmergCall - is marked by rapid response of the key decision-maker to an unexpected situation presented during a phone call coming from a customer attended regularly by another production unit of 18F-FDG located out of the range considered so far feasible to be supplied starting from the production unit of IPEN. Despite these difficulties, providing services to that client was not immediately discarded by the key decision maker. Following on, the solution previewed by the key-decision maker was built and implemented - EmergEffort. This decision broke the paradigm that 18F-FDG could only be distributed by roadway considering a radius of 100 km from the production site. Once proven the feasibility of the new manufacturing strategy and logistics efforts the following effort focused on building a solution that would give greater security in the continuity of supply to customers given the possibility of unplanned interruptions in production facilities. Then the back up agreement decision between the production units of São Paulo and Rio de Janeiro – BackUpNeg – was developed. An unexpected assymetrical mutual back up deal had to be closed, but an underlying objective was intended: the recognition of being a official back up installation in the short term but aiming the construction of a cyclotron fully dedicated to producing 18F-FDG that could be used effectively as a back-up. Next, the NewStrat decision was taken. This decision involved the choice between initiating immediately the expanded strategy supply of 18 F-FDG under risk of possible discontinuities or waiting at least two years to initiate the expanded strategy - time that the acquisition and implementation of a 18 F-FDG dedicated cyclotron would take. The first alternative was adopted.

Strategies may be unfulfilled, deliberate and emergent[9]. Mintzberg Ahlstrand and Lampel state that effective strategists mix deliberate and emergent strategies in such a way that reflect existing conditions, especially by the ability to predict and also to react to unexpected events. In the five decisions analyzed here it was found exactly this mixture between deliberate and emergent strategies basically due to decision-making processes well conducted - the elements of a quality decision are present in each of five decisions - which also led to right decisions - a significant number of new patients now have access to an emerging technology.

5. CONCLUSIONS

This study allowed the recovery of the trajectory of the development of production of 18F-FDG in Brazil. This story highlights the difficulty for developing a breakthrough technology in the public sector - surrounded by financial, legal and political constrains. The process through which important decisions are taken has a profound impact on the consequences of those decisions. Experienced decision makers can make quality decisions when they are equipped with the appropriate information, when they link the relevant decisions taken over time, when they use the right tactics at the right time and when the correct participants are involved at the right time throughout the decision making process. They also identify opportunities where others see problems, review the current strategies and develop new ones; they prepare themselves to deal with the uncertainties.

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ISBN: **978-85-99141-05-2**

Appendix 1

Interviews script

- How the problem was noticed? How it became clear that a decision would be necessary? Did some opportunity window happened that made easier to initiate a decision making process?
- Who participated in the problem identification? All people who should be involved participated in the discussions? What procedures were taken in order to clarify the problem and establish the objectives? Was there a need to create an artificial sense of urgency in order to take a decision?
- What were the objectives? Who participated in the discussions of the objectives? All people who should be involved participated in the discussions? The objectives were defined with all participants together or separately? Were the objectives discussed clearly or were ambiguous/opportunistically discussed?
- Did the decision making process suffered any form of information anchorage, or compromise escalation or exaggerated form to confirm initial expectations?
- During the decision making process were analogies with other situations expressed. Were arguments based on imitation/copy like "they did it, then we can also do it?" activated?
- Did any external consultancy participated in the decision making process?
- What were the alternatives considered? How the alternatives were generated? The process of solution generation was planned? Were brainstorming practices activated?
- Who was involved in the alternatives generation? All people who should be involved participated in this process? The alternatives were defined with all participants together or separately?
- During the decision making process, were consequences anticipation analysis performed? Were any forms of contingencies plans elaborated in case the decision fail or not reach the expected results?
- Was any idea generated or any decision taken along the process intuitively?
- Who was involved in the alternatives generation analysis? All people who should be involved participated in the discussions? The alternatives were defined with all participants together or separately? How alternatives were analyzed? Was any form of pre-condition analysis for an alternative developed in order to have it approved planned?
- The climate among the participants during the discussions involved an excess of harmony or were all participants free to express openly their ideas?
- What form of analysis were performed (pros-and-con analysis, technical and economic viability, pilot tests, etc.) Were practices like devil's advocacy activated? Was any golden rule activated to help the decision?
- Were any alternatives prematurely rejected? Labels were used to describe the alternatives?
- The consequences and the risk were deeply considered during the analysis? Past and future decisions were considered? Practices like intuitive analysis, persuasion or consensus were activated?
- Phenomena like excess confidence or control illusion were present during the decision making process? How these problems were dealt?
- Was any form of stakeholder's interest identification planned in order to have their interest better attended? Did any form of bargain happened in order to get the decision made?
- Did some form of data search or data analysis happened only to justify a decision that had been already taken? The decision was influenced by a possible negative impact over the participants of major responsibilities? The decision was influenced by a possible sanction or pressure from a higher authority?
- Was any form of previous thought developed concerning the arguments to be used to defend a preferential solution?