How can we optimise the pharmaceutical analysis of radiopharmaceutical pediatric prescriptions?

Pauline Leclerc, Solène Marie, Julien Fouque, Madar Olivier, Sandy Blondeel-Gomes

ABSTRACT

Objectives In France, dispensation is defined by the validation of a prescription associated with a pharmaceutical analysis, preparation of medication and provision of information necessary for proper use. There are very few data available in the literature that describe prescription analysis modality in radiopharmacy. The aim was to secure a place for paediatric prescription analysis in radiopharmacy by designing a flow chart validated by experts.

Methods Experts from different disciplines and health setups (ie, public, private) were selected to represent the various paediatric patient care processes. A review of the literature on pharmaceutical analysis and paediatric prescription in radiopharmacy was conducted. A Delphi approach comprising two rounds (Google Form survey) was used to validate the flow chart. Answers were graded according to a nine-point Likert scale for agreement. Open-ended questions allowed experts to comment on the propositions. A consensus between experts was reached if more than 70% of the experts agreed on an item and fewer than 30% disagreed.

Results Sixty-five experts were solicited: two oncopaediatricians, three nuclear medicine physicians, 46 radiopharmacists, three residents in radiopharmacy, one hospital pharmacist, five medical physicists, one pharmacy technician, two X-ray technicians and two patients who are pharmacists. The first round survey included a draft of the flow chart: 31 experts answered (48%). All professional disciplines were represented except pharmacy technician. The second round survey was sent with a new flow chart that had been improved by the experts’ comments. After 3 weeks, 18 answers were obtained (28%). After the first round, consensus was obtained for each item. Experts gave a total of 97 comments. The second flow chart had three steps: regulatory aspects, patient data, and radiopharmaceutical data, and it was accompanied by descriptive text explaining the field of application.

Conclusion The resulting flow chart will secure the pharmaceutical analysis step for this special patient population.

INTRODUCTION

In France, radiopharmaceuticals are regulated by two items of legislation. First, they are covered by ionising radiation legislation. Second, as they are medication, they must be prescribed by a nuclear medicine physician and managed by a radiopharmacist, who must ensure the dispensing process, including pharmaceutical analysis of the prescription. Radiopharmaceuticals can be used for diagnostic or therapeutic procedures. The effects of low-dose radiation exposure, which are encountered during diagnostic procedures in nuclear medicine, are poorly understood although several studies have suggested an overestimation of the risk. Particular attention is required in radionuclide therapy due to high activities that are administered. Furthermore, children appear to be more sensitive to ionising radiation than adults.

As pharmaceutical analysis is an essential step in guaranteeing the safety of the medication process, the French Health Authority evaluate this criterion during the hospital certification process. The importance of the pharmacist’s role in reducing the risk of errors in the paediatric population has been well described. Furthermore, the paediatric population has a higher risk of potentially dangerous medication errors than do adults. Pharmacokinetics is of particular importance in the paediatric population because of the physiological development from newborn to young adult, especially renal and skeletal immaturities, brown adipose tissue activation and membrane permeability. There are very few publications in the literature that describe the radiopharmaceutical circuit and safety modalities for children.

STUDY AIM

The aim of this study was to guarantee the safety of paediatric care processes by designing a radiopharmaceutical prescription analysis tool validated by experts.

ETHICS APPROVAL

Ethics approval was not required.

METHODS

A review of the literature was conducted by a radiopharmacist with over 10 years’ practical experience and a hospital pharmacy resident specialised in radiopharmacy. PubMed and ScienceDirect databases were consulted in successive iterations using the following MeSH keywords: (paediatric) pharmaceutical validation, (paediatric) pharmaceutical analysis prescription, paediatric prescription in nuclear medicine, radiopharmaceutical paediatric prescription, and paediatrics in nuclear medicine. Summaries of product characteristics and reference books were also consulted to retrieve paediatric recommendations for each radiopharmaceutical. Relevant articles in the French or English language from 2006 onwards were selected by the team.

To highlight several steps of the pharmaceutical analysis we chose a flow chart presentation. We validated the propositions by taking a Delphi
approach. By questioning experts by means of successive questionnaires, this method allowed a convergence of opinion and a general consensus on topics. A first draft of a flow chart was designed and proposed to experts (online supplemental file 1). Their responses were analysed in order to improve the flow chart. Experts were selected to represent all the paediatric patient care processes from the examination or treatment prescription to the administration of radiopharmaceuticals. We solicited paediatricians who prescribe nuclear medicine examinations or treatments, nuclear medicine physicians who prescribe radiopharmaceuticals, radiopharmacists and residents in radiopharmacy who analyse and validate radiopharmaceutical prescriptions, hospital pharmacists who validate prescriptions for paediatric populations, pharmacy technicians and X-ray technicians who are in charge of the preparation and dispensation of radiopharmaceuticals, as well as patients who are pharmacists. The expertise of these individuals was essential in gaining an overall view of all the pharmaceutical processes.

A survey (Google Forms) was circulated by email. Answers were graded according to a nine-point Likert scale for agreement (1=total disagreement and 9=total agreement). Consensus was considered to be reached if more than 70% of the experts agreed on an item (score between 7 and 9) and fewer than 30% disagreed (score between 1 and 3). Open-ended questions allowed experts to comment on the propositions. Experts could also answer ‘do not want to respond’ or ‘cannot respond’ to each question.

The following data concerning the experts was also collected: profession, number of years of experience and conflicts of interest disclosures.

Experts had a 4-week deadline (first round) and a 3-week deadline (second round) by which to respond. Email reminders were sent 1 week before the deadline.

RESULTS
To create the first draft of the flow chart, a review of the literature was conducted to determine different steps of the prescription analysis. We categorised analysis criteria into five groups: examination or treatment planned, legal requirements of the prescription, patient data, radiopharmaceutical data, and dose preparation.

The first phase of the analysis concerned planned examinations or treatments and focused on premedication. We concentrated on thyroid blockage which is specific to some iodine radiopharmaceuticals. A blocking agent must be administered to patients at risk for thyroid accumulation of the drug: [123I]iodobenguane, [131I]iodomethyl norcholesterol, [123I]oiflupane and [125I]iodinated human albumin. Several drugs are available to protect the thyroid: Lugol’s iodine solution, potassium iodine tablets, sodium perchlorate tablets or oral solution. In France, Lugol’s iodine solution 1% is often used for children because of its easy availability. For the second part of the analysis, we studied legislation requirements for a radiopharmaceutical prescription. According to the legislation, all the usual data relating to the non-radiopharmaceutical prescription must be checked. In addition, the dosage must be expressed in Becquerels (Bq). Four radiopharmaceuticals, which can be administered to children, must have specific plasma-derived medicinal product (PDMP) traceability: [123I]iodated human albumin, [99mTc]human nanocollodial albumin, [99mTc]macroaggregated human albumin and [99mTc]human serum albumin. The physician has an obligation to inform the patient or their legal representative about any risks. The information concerning the prescription, the dispensation and the administration must be archived for 40 years.

Patient data analysis was the third step of the first flow chart. We studied paediatric population physiological specifics, physiological changes during childhood and their consequences for radiopharmaceutical pharmacokinetics. Renal and hepatic functions are two examples of physiological modifications during childhood. In addition to these modifications, special attention is required for children with renal or hepatic failure. Most recommendations are due to the renal excretion of radiopharmaceuticals. In cases of renal failure, particular attention should be paid to three radiopharmaceuticals: [111In]pentetreotide is not recommended, and [99mTc]DMSA and [99mTc]oxidronate administration must be followed by a 6- to 24-hour delay before image acquisition to guarantee the quality of the examination. 18F-Fluorodeoxyglucose (18F-FDG) image quality is affected by a high background activity but administration is not contraindicated.

The fourth step concerns radiopharmaceutical contraindications and dosage. Summaries of product characteristics contained recommendations of contraindication for the paediatric population for all radiopharmaceuticals available in France. We recorded several radiopharmaceuticals containing pharmaceutical excipients with adverse events. Benzyl alcohol contained in [125I]iodinated human albumin, [67Ga]gallium citrate, [123I]iodine 123 iobenguane and [131I]iodomethyl norcholesterol may cause a ‘gasping syndrome’. The presence of ethyl alcohol in some radiopharmaceutical specialties (18F-FDG and [131I]iodomethyl norcholesterol) must be considered before administration. Other radiopharmaceuticals contain ethyl alcohol but are not indicated in children.

Summaries of product characteristics mention the dosage for the paediatric population. Different methods exist in nuclear medicine to calculate paediatric doses. Paediatric dosage is based on the age of the patient, weight, height or body surface area and must be adapted to acquisition. Dynamic acquisition requires higher doses than static acquisition. Camera technologies are evolving and the dose can be reduced without diminishing the image quality but minimum activity is needed to perform an adequate examination. The European Association of Nuclear Medicine (EANM) developed a method to calculate the optimum administrated activity for the paediatric population called EANM Paediatric Dosage Cards. The Paediatric and Dosimetry Committees of the EANM categorised radiopharmaceuticals into three classes: renal tracers are in class A, thyroid tracers in class C and other radiopharmaceuticals are in class B. To obtain the recommended dosage the baseline activity value has to be calculated using the multiples provided for each radiopharmaceutical class. Only six isotopes radionuclides are referenced in dosage cards. The last step concerned recommendations provided by the radiopharmacists, which are useful for the preparation of the radiopharmaceutical (eg, the need for a specific medical device or volume of drugs according to the route of administration).

All the data were mentioned in the draft flow chart that was proposed to the experts.

Sixty-five experts were solicited: two oncopediatricians, three nuclear medicine physicians, 46 radiopharmacists, three residents in radiopharmacy, one hospital pharmacist, five medical physicists, one pharmacy technician, two X-ray technicians and two patients who are pharmacists. The first round survey was composed of six questions and was associated with the first flow chart (online supplemental file 2). Questions focused on both form and content. Each question ended with space for comments.
Thirty-one experts answered (48%). All professional disciplines were represented except pharmacy technician. Average experience was 9 years (range, 6 months–25 years). No conflicts of interest were reported.

A consensus was obtained with the first round; however, nine experts wanted simplification and/or restructuring of the flow chart. These individuals proposed changing the chronology of several items. Five experts wanted more detail in the part concerning information to the patient. According to the experts, several items were missing in the ‘legal requirements of the prescription’ step (date of the prescription and hospital) and in the ‘patient’ step (sex).

We removed the examination or treatment planning step and the recommendation for the preparation step from the flow chart.
chart. We decided to have three steps in the new flow chart: regulatory aspects, patient data, and radiopharmaceutical data (online supplemental file 3). To keep the information about the two deleted steps linked to the prescription analysis, we wrote some introductory text defining the flow chart’s scope and briefly describing the two removed steps. The text also described the legal considerations for pharmaceutical analysis in the paediatric population.

To ensure patient safety, a pharmacist can refuse to dispense a drug if he considers this necessary (Article 4235–61 of French Public Health Code) and has to immediately inform the prescribing physician of his refusal. The pharmacist also has to evaluate preparation feasibility: namely, supply of the radiopharmaceuticals, human and material resources for preparation, and quality control. Among other things, the pharmacist must check the French Nuclear Safety Authority (ASN) authorisation for the radionuclides and the maximum quantity allowed. After the analysis prescription process, recommendations should be provided to the person in charge of the preparation if necessary: syringe type (luer or luer-lock connection), volume of administration, and so on.

The flow chart, accompanied with the text, was proposed to the experts once again. The second round survey (six questions) was sent to the experts who answered the first survey (online supplemental file 2). Eighteen answers were obtained after 3 weeks (28%). After the first round, consensus was obtained for every item except one. Experts gave a total of 97 comments (first round: 60; second round: 37), of which 20 concerned the flow chart form.

After analysis of the second round, the introductory text was considered to be clear. Two experts thought that the text was too long. One expert considered the necessity of a pharmacovigilance conscious approach. Four experts considered checking every item in the patient file to be very difficult in daily practice.

Two experts wanted to add the unique patient identifier. Consensus was not reached for the item platelet count so we removed it.

Figure 1 shows the final flow chart composed of three steps instead of the initial five steps: regulatory aspects, patient data, and radiopharmaceutical data. Descriptive text explaining the fields of application introduced the flow chart and included important points regarding pharmaceutical analysis (Box 1).

**Box 1** Text explaining the fields of application introduces the flow chart and includes important points regarding pharmaceutical analysis.

**Text accompanying the flow chart for the pharmaceutical analysis of radiopharmaceutical pediatric prescriptions**

The dispensation of medication is defined in the Code de la Santé Publique (French Public Health Code) as the pharmaceutical acts associated with the delivery of medicine: pharmaceutical analysis of the medical prescription, supply of information and advice for correct usage of medication and preparation of doses to be administered.

This flow chart is applicable to radiopharmaceuticals (medication and implantable radioactive medical devices) prescribed for an examination or a treatment for patients under 18 years old. This flow chart does not concern medication prescribed under regulation, for clinical trials or delivered outside the hospital (thyroid blockers, anxiolytic drugs, etc.).

The following items are included in the preliminary request for pharmaceutical analysis of paediatric radiopharmaceutical prescription:

- Fixed appointment (date, hours of the examination or treatment)
- For a computerised prescription, parameters in relation to training (prescription for nuclear medicine physicians and pharmaceutical validation for radiopharmacists)
- Availability of the medication
- Availability of the medical devices necessary for the preparation
- Testing of the equipment (flow hood)
- Validation of documents (procedures, patient advice leaflet)
- If possible, putting in place the specific circuit for the paediatric patient.

The pharmaceutical analysis is realised by means of three verification steps:

- Presence of regulatory data (computerisation could secure this step)
- Patient data
- Medication data.

During the verification process, additional information may be required from the prescriber.

The pharmacist gives advice during the pharmaceutical analysis. This advice must be traceable. The article R 4235–61 of the Code de la Santé Publique states that the pharmacist should refuse to deliver medication if this is necessary in the interests of the health of the patient. The pharmacist should immediately inform the prescriber of his refusal and the action must be traceable.

Information is collected during pharmaceutical analysis and transmitted to the person in charge of the preparation of doses to be administered:

- Choice of medical devices (eg, luer-lock syringe for central intravenous injection)
- Incompatibility of the material
- Specific procedures for preparation (example: respect of the number for aggregated human albumin).

During pharmaceutical analysis, the pharmacist can ask the prescribing physician for complementary information. The pharmacist gives an expert opinion which must be traceable.

In radiopharmacy we do not classify the analysis as does the French Society of Clinical Pharmacy (SFPC). Three levels of
analysis of prescription are defined according to the involvement of the clinical pharmacist. This classification applies to therapeutic drugs but not to diagnostic radiopharmaceuticals. For SFPC, the first level is a simple analysis of the treatment prescription, the second level includes an analysis of all the different prescriptions, and the third level involves pharmaceutical monitoring. Access to the patient medical history is different in each health setup branch and the flow chart must be adapted to this constraint. Human resources should be linked to allow all possible checks to be made.

In France, any adverse event due to radiopharmaceuticals must be reported to the French health authority. Different studies in various countries on the adverse reactions reveal their rarity. A robust pharmacovigilance system is essential and allows sharing of information. Such data will help radiopharmacists and other healthcare workers to improve patient care.

The Delphi approach was an easy means of reaching a consensus between experts from different disciplines and health setups (ie, public, private) and geographical locations. An unusual feature of the present study was that we solicited opinions from experts concerned with the steps in the medication circuit for paediatric patients. Paediatric patients themselves could not be surveyed. We also solicited opinions from patients who are pharmacists so as to have another viewpoint for the flow chart. Only one responded to the survey—a hospital pharmacist—and he shares the view of other participants on the flow chart.

The anonymity and confidentiality of responses were the most important advantages of this method, which help avoid potential confrontations between experts. The main drawback was the lack of discussion between experts.

The ratios of the various experts who participated in this study demonstrate their interest in the development of this tool. The flow chart is a tool to help pharmacists to standardise and secure the prescription analysis process. Dubois et al have previously demonstrated the importance of training in pharmaceutical analysis.

The introductory text is essential for understanding the flow chart and briefly explaining the different aspects of the pharmaceutical analysis that have been detailed previously. The developed tool is simple to understand.

CONCLUSIONS
We have created the first flow chart for radiopharmaceutical prescription analysis in paediatrics. The resulting tool is currently being used in our department and has allowed us to secure prescription analysis in radiopharmacy, which is an essential step in guaranteeing the safety of the medication process. The flow chart concept is proposed to software editors to improve their products and patient security.

What this paper adds

What is already known on this subject

⇒ Very few publications describe the radiopharmaceutical circuit and safety modalities for children.

What this study adds

⇒ We are proposing the first flow chart for radiopharmaceutical prescription analysis in paediatrics validated by experts.
⇒ This tool will secure prescription analysis in radiopharmacy.

Acknowledgements The authors would like to thank the participants who kindly responded to the survey, and Tobias Ryan for English correction of the manuscript.

Contributors PL: two-stage survey and final flow chart design. SM and SB-G: survey analysis. MO and JF: bibliography and initial flow chart design.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests The authors declare that they have no competing interests in this study. The authors declare that they did not receive funding for this study.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

ORCID iDs
Pauline Leclerc http://orcid.org/0000-0002-4508-4207
Sandy Blondeel-Gomes http://orcid.org/0000-0002-6437-8753

REFERENCES


Original research

21 Potdevin-Verdier J. Evaluation des pratiques professionnelles en radiopharmacie et amélioration de la sécurité du médicament radiopharmaceutique au CHR de Metz-Thionville. These, Faculté de pharmacie de Nancy, Université de Lorraine, 2013.


FLOW CHART FOR RADIOPHARMACEUTICAL PRESCRIPTION ANALYSIS IN PEDIATRICS

1. Exam or treatment planned

   Information /advice
   - Explanation child/parents: Procedure/radiation safety/ fasting, / No glucose infusion /waste management (urine ...) / avoid close contact

   Premedication check (prescribed by nuclear medicine physician)
   - Blockage Thyroid for iodine 131 I, 125I, 123I radiopharmaceuticals (except thyroid exam)

   Exam date

2. Regulatory data of the prescription

   Validity of the prescription
   Date
   Prescriber identification /signature
   Authorization of the prescriber

3. Patient information

   Identification of the patient
   (name, first name, unique patient identifier)
   Age (date of birth)
   Weight, length/height, body surface area
   Access to patient file ?
   Pathology (indication)
   Inclusion in a clinical trial ?
   Allergy, intolerance
   Time between radiopharmaceutical administration and chemotherapy/radiotherapy / hematopoietic growth factors

4. Radiopharmaceutical prescribed

   Indication exam relevance
   Choice of the radiopharmaceutical
   Protocol
   EANM dosage card, minimum activity for image quality, 131I iobenguane: dosage determined using a pre therapeutic dose
   Contra indication
   Drug interactions
   Specific circuit radiopharmaceutical
   Route and mode of administration
   Validation +/- pharmaceutical opinion (traceability)
   Injection site information (left, right, peripheral or central line)

5. Dose preparation

   Information to technicians in charge of preparation
   Syringe preparation or other preparation
   Specificity of the preparations for clinical trial
   Devices choices for the preparation (luer, luer lock): Compatibility between radiopharmaceutical and device
   Specificity of the pediatric preparation (small volume, dilution...)
   Macroaggregates number for specific radiopharmaceutical
First survey

1- What do you think about the 5 steps of the flowchart? (graded: 1 not relevant to 9: very relevant)

<table>
<thead>
<tr>
<th>Do not want to respond</th>
<th>Cannot respond</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exam or treatment planned</td>
<td>Consensus reached</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regulatory data of the prescription</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient information</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiopharmaceutical prescribed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dose preparation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2- Are the names of the items suited? Do you want to add or delete items?

3- What do you think about items related to “exam or treatment planned” (graded: 1 not relevant to 9: very relevant)

<table>
<thead>
<tr>
<th>Do not want to respond</th>
<th>Cannot respond</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information, advice to patients or parents</td>
<td>Consensus reached</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Premedication check</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date of the exam</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4- Are the names of the items suited? Do you want to add or delete items?

5- What do you think about items related to “Regulatory data of the prescription of the prescription” (graded: 1 not relevant to 9: very relevant)

<table>
<thead>
<tr>
<th>Do not want to respond</th>
<th>Cannot respond</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Validity of the prescription</td>
<td>Consensus reached</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prescriber identification/Signature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Authorization of the prescriber</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6- Are the names of the items suited? Do you want to add or delete items?
7- What do you think about items related to “patient” (graded: 1 not relevant to 9: very relevant)

<table>
<thead>
<tr>
<th>Item</th>
<th>Do not want to respond</th>
<th>Cannot respond</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age/date of birth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight, length/height, body surface area and BMI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to patient file : pathology, allergy, intolerance, inclusion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in a clinical trial, other prescription, time between exams</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to biological data (liver and kidney functions, platelet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>count)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Consensus reached

8- Are the names of the items suited? Do you want to add or delete items?

9- What do you think about items related to “Radiopharmaceutical data” (graded: 1 not relevant to 9: very relevant)

<table>
<thead>
<tr>
<th>Item</th>
<th>Do not want to respond</th>
<th>Cannot respond</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indication</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiopharmaceutical choice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protocol</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dosage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drug interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contraindication</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiopharmaceutical availability (drug order)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Route and mode of administration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific circuit radiopharmaceutical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injection site information</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Validation and pharmaceutical opinion,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Consensus reached

10- Are the names of the items suited? Do you want to add or delete items?

11- What do you think about items related to “Dose preparation ” (graded: 1 not relevant to 9: very relevant)

<table>
<thead>
<tr>
<th>Item</th>
<th>Do not</th>
<th>Cannot</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indication</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiopharmaceutical choice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protocol</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dosage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drug interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contraindication</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiopharmaceutical availability (drug order)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Route and mode of administration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific circuit radiopharmaceutical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injection site information</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Validation and pharmaceutical opinion,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Do not

Cannot

1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9

<table>
<thead>
<tr>
<th>Information to technicians in charge of preparation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Syringe preparation or other preparation</td>
<td></td>
</tr>
<tr>
<td>Specificity of the pediatric preparations (small volume, dilution...)</td>
<td></td>
</tr>
<tr>
<td>Specificity of the preparations for clinical trial</td>
<td>Consensus reached</td>
</tr>
<tr>
<td>Devices choices for preparation (luer, luer lock)- Compatibility between radiopharmaceutical and device</td>
<td></td>
</tr>
<tr>
<td>Macroaggregates number for specific radiopharmaceutical</td>
<td></td>
</tr>
</tbody>
</table>

12. Are the names of the items suited? Do you want to add or delete items?

13. Concerning conflict of interest
   - I declare I do not have a conflict of interest
   - Other

14. Are you?
   - Radiopharmacist
   - Nuclear medicine physicians
   - Resident in radiopharmacy
   - Medical physicists
   - Hospital pharmacist
   - X-ray technicians
   - Pharmacy technician
   - Other:

---

BMJ Publishing Group Limited (BMJ) disclaims all liability and responsibility arising from any reliance placed on this supplemental material which has been supplied by the author(s)
Second survey

1- Are you?

☐ Radiopharmacist
☐ Nuclear medicine physicians
☐ Resident in radiopharmacy
☐ Medical physicists
☐ Hospital pharmacist
☐ X-ray technicians
☐ Pharmacy technician
☐ Other:

2- So you think about the text introducing the flow chart? (graded: 1 not relevant to 9: very relevant)

<table>
<thead>
<tr>
<th>Do not want to respond</th>
<th>Cannot respond</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>Consensus reached</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field of application</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prerequisite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pharmaceutical analysis description</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information needed for preparation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3- Are the names of the items suited? Do you want to add or delete items?

4- What do you think about the 3 steps flow chart? (graded: 1 not relevant to 9: very relevant)

<table>
<thead>
<tr>
<th>Do not want to respond</th>
<th>Cannot respond</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1: Regulatory data</td>
<td>Consensus reached</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 2: Patient data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 3: Radiopharmaceutical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5- Are the names of the items suited? Do you want to add or delete items?
6- What do you think about items related to “Legal requirements” (graded: 1 not relevant to 9: very relevant)

<table>
<thead>
<tr>
<th>Item</th>
<th>Do not want to respond</th>
<th>Cannot respond</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of the prescription</td>
<td>Consensus reached</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prescriber identification</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habilitation of the prescriber</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference to hospital and nuclear medicine department</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification of the patient (name, first name, sex, age, Weight, length/height, unique patient identifier)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>International non-proprietary name prescription</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific prescription for product derived from human blood or human plasma</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7- Are the names of the items suited? Do you want to add or delete items?

8- What do you think about items related to “patient” (graded: 1 not relevant to 9: very relevant)

<table>
<thead>
<tr>
<th>Item</th>
<th>Do not want to respond</th>
<th>Cannot respond</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight check</td>
<td>Consensus reached</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pathology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drug history</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual prescription</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allergy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intolerance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time between radiopharmaceutical administration and chemotherapy/radiotherapy/hematopoietic growth factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imaging exam history</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kidney function</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liver function</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platelet count</td>
<td>Consensus not reached</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
9- Are the names of the items suited? Do you want to add or delete items?

10- What do you think about items related to “Radiopharmaceutical” (graded: 1 not relevant to 9: very relevant)

<table>
<thead>
<tr>
<th>Item</th>
<th>Do not want to respond</th>
<th>Cannot respond</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compliance between exam request and the radiopharmaceutical prescribed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indication</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compliance to local protocol</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dosage (EANM dosage card, minimum activity)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contra indication (age, new born, pregnancy, presence of alcohol benzylic ...)</td>
<td>Consensus reached</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drug interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Route and mode of administration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

11- Are the names of the items suited? Do you want to add or delete items?

12- Other comments
SECOND SURVEY
TEXT ACCOMPANYING THE FLOW CHART
FOR THE PHARMACEUTICAL ANALYSIS
OF RADIOPHARMACEUTICAL PEDIATRIC PRESCRIPTION

The dispensation of medication is defined in the Code de la Santé Publique (French Public Health Code) as the pharmaceutical acts associated to the delivery of medicine: pharmaceutical analysis of the medical prescription, supply of information and advices for correct usage of medication and preparation of doses to be administered.

This flow chart is applicable to radiopharmaceuticals (medication and implantable radioactive medical devices) prescribed for an exam or a treatment for patients under 18 years old. This flow chart do not concern medication under regulation prescribed, for clinical trials or delivered outside the hospital (thyroid blockers, anxiolytic drugs ...)

The following items included in the preliminary requests for pharmaceutical analysis of pediatric radiopharmaceutical prescription:

- Fixed appointment (date, hours of the exam or treatment);
- For computerized prescription, parameters in relation to training (prescription for nuclear medicine physicians and pharmaceutical validation for radiopharmacists);
- Availability of the medication ;
- Availability of the medical devices necessary for the preparation;
- Testing of the equipment (flow hood) ;
- Validation of documents (procedures, patient advice leaflet) containing advices to patient (fasting, pregnancy ...);
- If possible, putting in place of the specific circuit for pediatric patient.

The pharmaceutical analysis is realized in three steps of verification:

- Presence of regulatory data (computerization could secure this step);
- Patient data (check must be adapted to each radiopharmaceutcial);
- Medication data.

During these verifications, additional information may be required from the prescriber.

The pharmacist gives advice during the pharmaceutical analysis. This advice must be traceable. The article R4235-61 of the Code de la Santé Publique stables that the pharmacist should refuse to deliver medication if necessary, in the interest of the health of the patient. The pharmacist should immediately inform the prescriber of his refusal and it must traceable.

Information is collected during pharmaceutical analysis and transmitted to the person in charge of the preparation and/or preparation of doses to be administered:

- Choice of medical devices (example: luer lock syringe for central Intravenous injection...);
- Specific procedures for preparation (example: respect of the number for aggregated human albumin...)
SECOND SURVEY
FLOW CHART FOR RADIOPHARMACEUTICAL PRESCRIPTION ANALYSIS
IN PEDIATRICS

Medical prescription of the radiopharmaceuticals

Check legal requirements:
- date of prescription
- identification of prescribing physician (name and qualifications)
- signature
- authorization of prescribing physician
- name of hospital and nuclear service department
- patient identification: name, surname, sex, age (birth date), weight, height, ( +/- identification number)
- prescription in International Nonproprietary Names
- for blood-derived medicine: specific traceability

Regulatory compliance

no

Patient data:

- weight check

If patient’s medical record available, check:
- pathology
- medication history
- current prescriptions (not included medication)
- allergy
- intolerance
- respect for optimum interval between chemotherapy/radiotherapy/growth factor
- imagery history (other radiopharmaceutical prescriptions)

If necessary and if biological data available, check:
- renal function (creatinine)
- hepatic function
- platelet count

All items are OK

Radiopharmaceutical data, check:
- prescription compliance with request form
- indication mentioned in marketing authorization
- compliance with institutional protocols
- posology: minimum recommended dose for adequate imaging, iobenguane 131I posology is determined after pre
therapeutic administration of iobenguane 131I, dosage cards EANM
- contraindications: age (premature infants, newborn children, benzyl alcohol presence, pregnancy...)
- drug interactions
- route and mode of administration, specify injection site (left/right for Sentinel lymph node scintigraphy

All items are OK

Pharmaceutical validation
+/
pharmaceutical opinion drafting (traceability)