JJCR2017

From the analysis of image-guided biopsies to the specifications of a new robotic system and its associated workflow

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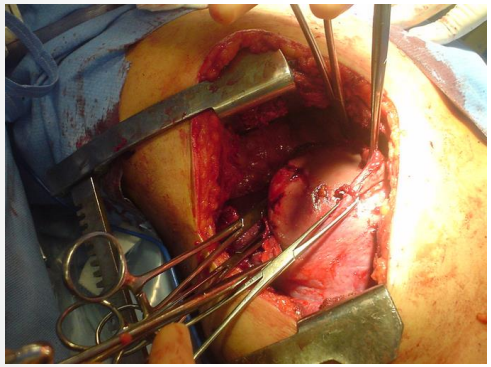
1. Medical context



Traditional surgery

Laparoscopy

Interventional radiology

Trend:

- Less invasive procedures

But also:

- Early and focal treatment
- Adapt treatment to pathology → biopsies: key for local information about tumour

1. Context : interventional radiology

- Use images to guide the needle

- Good tumour visualization with the following imaging modalities:

CT

CBCT

Better patient- access

MRI

No X-rays, soft tissue contrast

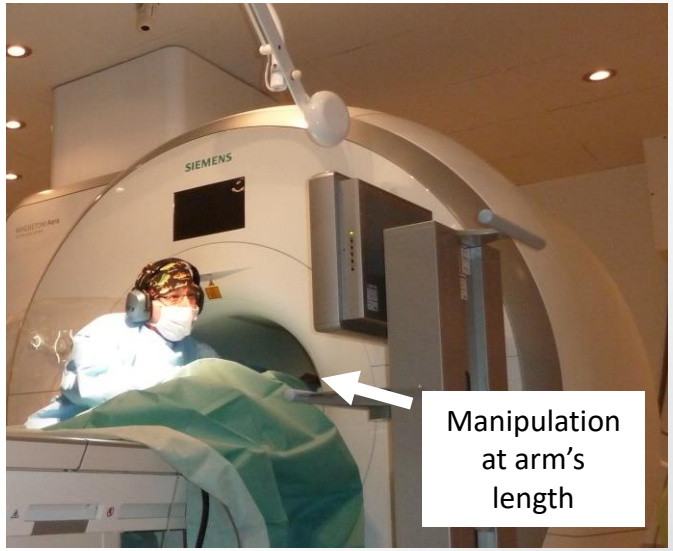
→ **Growing trend**

1. Context : interventional radiology

- Issues
  - CT, CBCT: X-ray exposure
  - MRI: patient access

Procedures are
- Difficult to perform
- Experience-dependent
- Risky for the doctor

→ **Robotic assistance of great interest**



1. State of the art and goals

- Most systems are designed for CT
- Few are CT and MRI-compatible
- None to assist for CT, MRI and CBCT procedures

- Radiologist's feedback: existing systems lack of efficiency because of the important modification of the manual practice

Innomotion, INNOMEDIC GmbH, Herxheim, Germany

Goal

- To build a single system for the 3 modalities
- To make it efficient by staying close to the manual gesture

Method

- Analysis of manual gestures for the identification of:
  - the required functionalities
  - their associated workflow
- Validation and refinement of functionalities and workflow through pre-clinical experiment

1. Methods

Interviews

- France, Germany, Switzerland
- Interview grid: difficulties, training time, expected added-value of robotics + feedback, trends…

Observation of procedures

- France, Germany
- > 35h of observations on MRI, CT, CBCT
- Observation grid
  - Qualitative analysis: difficulty of task, haptic feeling, …
  - Quantitative analysis: procedure times, target size, number of try & error

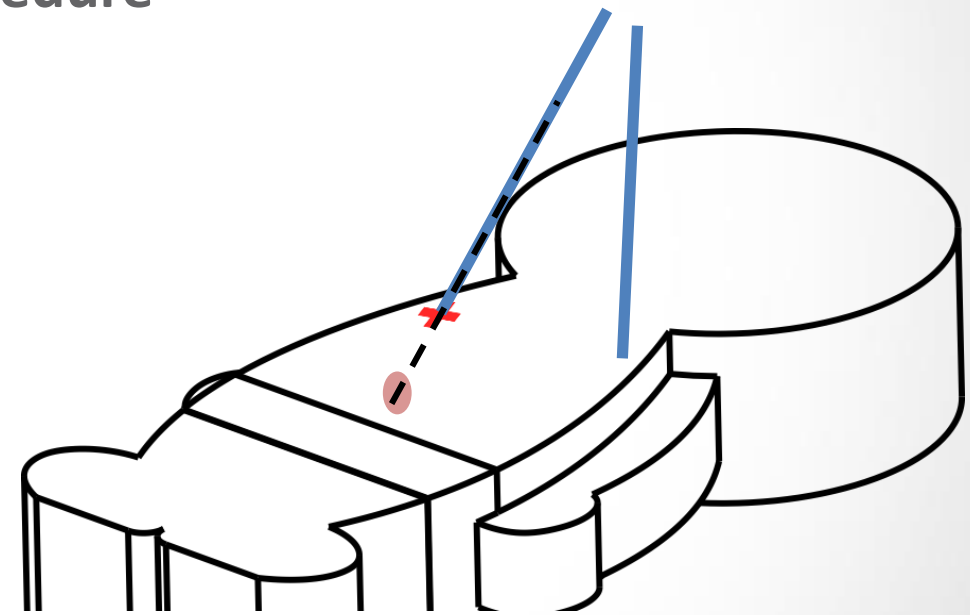
1. Methods

Prototype evaluation

- Strasbourg
- CBCT, on phantom
- Robotic insertion
- Accuracy, X-ray exposure, procedure time
- Feedback from radiologist

2. Results: Manual biopsy procedure

1. Intra-operative planning
2. Determination of the entry point on the patient → Easy task
3. Patient preparation.
4. Superficial anaesthesia.
5. **Deep anaesthesia**
6. **Placement of coaxial needle in the tumour** → Difficult task
7. Biopsy puncture.



2. Results: difficulties in the manual procedure

Imager	Difficulties
CT	Orientation and insertion • No real-time imaging (X-rays) • Iterative manipulation/imaging → difficult, risky

CBCT	• Orientation
	  • Real-time imaging
	  • Needle manipulation with pliers → lack of dexterity
	  • X-ray exposure
	• Insertion: no real-time visualization

MRI	• Orientation and insertion
	  • Real-time imaging
	  • Patient access → difficult to be precise
	  • Fatiguing position

2. Results: Robotized workflow

1. Intra-operative planning
2. Determination of the entry point on the patient
3. Patient preparation
4. Superficial anaesthesia
5. **Robot installation**
   Positioning: **manual**
6. Deep anaesthesia
   Orientation: **remote manipulation with robot**
   Insertion: **manual**
7. Placement of coaxial needle in the tumour
   Orientation: **remote manipulation with robot**
   Insertion: **remote manipulation with robot**
   information feedback on membrane puncturing
   trajectory adjustement during insertion
8. Biopsy puncture

Robot holds the orientation

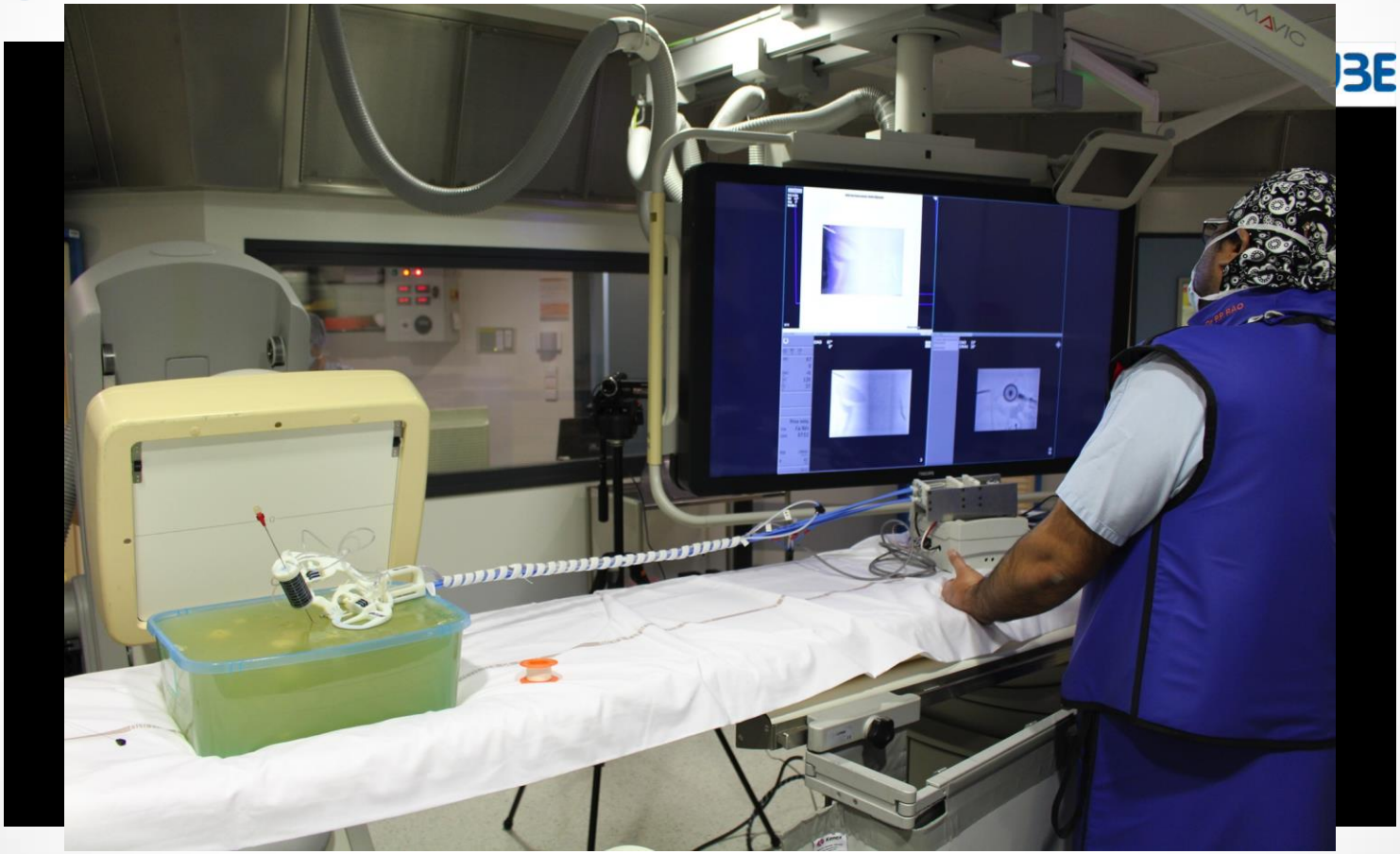
2. Robotized procedure: added-value

Imager	Robotized procedure
CT	Use of CT fluoroscopy without exposure: • Real-time visualization during orientation and insertion

CBCT	• Orientation
	  • Fine needle manipulation
	  • Less X-ray exposure
	• Insertion: real-time visualization without exposure to X-rays

MRI	• Orientation and insertion
	  • Accessibility issue solved by telemanipulation
	  • Improved dexterity
	  • Comfortable position

2. Validation and refinement of functionalities



Validated points

- Positioning
- Remote orientation and insertion

To be improved

- Intuitive control of needle orientation

Conclusion

- Identification of difficulties and expected added-value of robot
- Identification and quantification of required functionalities for a use in CT, MRI, CBCT
- Definition of the associated robotized workflow for CT, MRI, CBCT in collaboration with the radiologists
- Validation and refinement through pre-clinical experiment

Future work

- Improvement of a prototype previously developed in the lab
- Design of a new prototype taking into account sterilization and safety
- Integration of information feedback on membrane puncturing
- Integration of trajectory correction functionality

Thank you for your attention.

Questions?