PET/CT Guided Interventions

An introduction to using the core capabilities of hybridized PET/CT for innovative applications in medical practice

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The presenter claims no conflict of interest with or financial gain from organizations, institutions, manufacturers, and other entities that may be mentioned in this presentation.
Hello

Michener/U of T & SickKids
- Medical Radiation Sciences, Nuclear Medicine

Sarnia, ON
- Nuclear Medicine

Saskatoon, SK
- Nuclear Medicine & PET/CT
- Saskatoon Health Region

University of Toronto
- Master of Management of Innovation (MMI, 2017)
- Biomedical Zone

I’m passionate about innovation and the unlimited possibilities of a healthcare system enabled by technology.
1) PET/CT Guided Biopsies
   • Biopsy basics
   • Benefits & Limitations
   • How PET/CT can help
   • Advantages, Disadvantages & Considerations
   • Case

2) A Brief Mention of PET/CT Guided Radiation Therapy

3) Potential Future Prospects
PET/CT Guided Interventions

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PET/CT Guided Biopsies
Biopsy Basics

What is a biopsy?
Removal of a tissue sample for histological analysis

Why are they sometimes required?
To determine if abnormal tissue is malignant or benign

What are some indications?
Presence/extent of cancer, infection, certain diseases, fertility, inflammation, transplantation
Histological analysis of various stains of normal esophageal epithelial tissue versus EID versus well-differentiated and poorly differentiated ESCC shows marked differences in microscopic anatomic structure when comparing different immunochemical markers for disease.

(Esophageal carcinoma is an age-related neoplasm with a 5-year overall survival rate of less than 35%)

Incisional Biopsies
• Only a small sample of the tissue of interest is removed

Excisional Biopsies
• More involved procedure during which an entire lump or lesion is removed
• Clinical margins
• Aka surgical/open biopsies
Different Types of Biopsies

**Bone Marrow Biopsies**
AKA bone marrow aspiration; Removal of bone marrow, blood, and a small piece of bone by inserting a needle into the iliac crest or other bone (core biopsy)

**Endoscopic Biopsies**
A fiber-optic endoscope is inserted through a natural orifice or a small incision, and used to view the abnormal or suspicious area before biopsy

**Skin Biopsies**
AKA cutaneous biopsies, removal of skin cells; the type of skin biopsy will depend on the type and extent of the condition (shave, punch, in/excisional)
Different Types of Biopsies

Needle Biopsies
- A thin needle is inserted through the skin to remove tiny samples of abnormal tissue
- Fine Needle Biopsy
- Core Needle Biopsy
- Image-Guided Biopsy
  - CT, fluoroscopy, US, MR
  - Allows the physician to assess suspicious areas that can’t be felt though skin using real-time images
Benefits & Limitations

- Definitive diagnosis
- Fairly reliable method
- Individualized treatment (tumor stage, cell-typing)
- Generally not a painful procedure
- Can be done as an outpatient without hospital stay
- Less invasive vs open surgery
- Short recovery time

- False-positives/false-negatives
- Can be inconclusive
- Inadequate sample size or incorrect location
- Unsuitable biopsy method
- Lack of a safe access route
- Uncooperative patients
- Contraindications (i.e. uncontrolled bleeding conditions)
Patients with breast core needle biopsies: 988
False negatives of all biopsy results in the study: 2.2%
Resulting from a radiological mistake: 36%
Underestimation rate for all diagnosed cancers: 10.4%

The Question
How can we overcome the limitations of biopsies?

False positives, false negatives, inconclusive results
Stressful for patients, family members, and the healthcare team

Technical problems and/or not sampling the correct tissue
Sometimes it is difficult to identify the area(s) to be biopsied

Repeat biopsies for difficult cases leads to increased time & cost
Stressful for patients, longer time for definitive diagnosis, and costly
A Possible Solution
Apply core capabilities of PET/CT to guide biopsies

An innovative approach
Increasing recognition and application; global forecasted growth for PET scanner market: CAGR of 4.7% to 2027

Improve accuracy for difficult cases
New applications forecast further increases in utility; reduce risks & repeats

Cost-savings and safety for tough cases
Reduce the cost of repeat biopsies, and enhance clinical decision-making

Source: http://www.auntminnie.com/index.aspx?sec=sup&sub=mol&pag=dis&ItemID=115325
 PET/CT guided biopsies

Two ways information can be integrated:

Pre-procedural PET imaging is reviewed and retrospectively fused with CT and/or MR images, and used to plan the biopsy with intra-procedural CT.

Real-time PET/CT images are acquired with intra-procedural non-enhanced, diagnostic CT imaging and displayed on a single screen as the biopsy occurs.
Real-time PET/CT-biopsies

1. Inform the patient
2. Prep for PET/CT
3. Acquire PET/CT
4. Interpret scan
5. Plan the biopsy
6. Perform biopsy
7. Observe patient

Real-time PET/CT-biopsies

Inform the patient beforehand about the procedure, including:

• Why this method? How will it be performed?
• Benefits and risks
• A blood test done prior
  • Biopsy contraindication: platelet count less than 100k/u
• Answer any questions and address concerns!!
Prep the patient for the PET/CT scan, including:

- NPO 6 hrs, non-exercising
- Document any chemo and/or radiation therapy, and last done
- Sites will differ in what they ask
- Medications
- Working IV
- No distractions
Real-time PET/CT-biopsies

PET/CT acquisition
FDG: 5 to 12 mCi (185-444 MBq)
40 to 60 min-uptake + imaging time

Followed by interpretation by NM physician and radiologist performing the biopsy
Real-time PET/CT-biopsies

Determine biopsy site and needle trajectory (radiologist)

Real-time PET/CT-biopsies

Biopsy with PET/CT guidance:

- Position and immobilize patient
- Local anaesthesia/sedation
- Adjustments of biopsy needle insertion with CT component of unit if necessary
- 1 bed PET/CT to confirm
- Biopsy
- Post-procedure observation
Real-time PET/CT-biopsies

“Seven years in the making, this magnificent facility is a result of shared vision and collaboration. The close proximity of radiology, surgery, and endoscopy will produce innovations that advance the medicine of the 21st century and also provide a superb environment for our patients.”

Hedvig Hricak, Chair of Dept of Radiology, MSKCC
Real-time PET/CT-biopsies

Data from 2011 to 2013

Bones (n=33)
Liver (n=26)
Soft tissues (n=18)
Lung (n=15)
Abdo (n=14)
TOTAL: 106 biopsies

255 MBq FDG
Mean max SUV: 8.8

100% diagnostic success

Male, 60
Hx of oropharyngeal carcinoma

A. Axial FDG PET/CT shows uptake on left iliac bone – highly suspicious (SUV 10.2)
B. Axial non-contrast CT shows no correlate
C. Needle biopsy of lesion. Pathologist confirmed metastasis

Real-time PET/CT-biopsies

Female, 70
Hx of follicular lymphoma

A. Axial FDG PET/CT shows 2 cm uptake in the spleen (SUV 8.2)
B. Axial non-contrast CT shows no correlate
C. Needle biopsy of lesion. Pathologist concluded granulomatous rxn

Quantitative FDG-PET/CT

Standardized Uptake Value (SUV)

- A quantitative tool to distinguish between malignant and benign lesions
- Typical cut-off value for malignant lesions is **2.5**
- Based on tracer concentration determined from image pixels that have the highest activity

**HOWEVER**

- Some slow-growing tumors may have little FDG uptake → not FDG-avid (i.e. prostate ca)
Advantages

• Pre-procedural imaging may not reflect current anatomic conditions
• Most current images = more accurate
• Patient position for imaging and biopsy
• Certain biopsy techniques can result in shifting of lesion in question
• PET/CT is highly sensitive & can identify lesions with no correlation in other modalities
• FDG uptake is not affected by the procedure itself and has demonstrated increased diagnostic value
• Correct target identification → increased confidence in clinical decision-making
• Cost-savings and personalized treatment decisions
Disadvantages

• The procedure itself may not be cost-effective and/or financially feasible

• Occupancy of the PET/CT suite and department workflow

• Limitations of PET/CT resolution

• PET/CT scanner gantry and patient size

• Patient safety

• Respiratory or cardiac artifacts degrade image quality and can cause co-registration errors
Other Considerations

Radiation burden to patient (repeat CT scans, dosing) as well as the interventional radiologist performing the biopsy (exposure)

Radiation safety concerns
Case 1

Male, 73
Hx of prostate ca → Tx radial prostatectomy 4 y prior
   Current PSA below detection limit
Hx of bladder carcinoma → Tx total cystectomy 5 m prior
F/U CT and NM bone scan 4 mo prior: 0 abnormalities

Persistent and increasing back pain → MRI showed multiple vertebral mets, incl. T7 compression fracture

Radiation therapy for pain relief and vertebral instability with incipient spinal stenosis (cord compression)

Targeted systemic chemotherapy planned; hospitalized for staging

Case 1

Additional spinal MRI and whole body CT confirmed the multiple vertebral mets

Transpedicular biopsy of T7 and S1 to determine origin of mets and Tx regimen

BUT no malignant cells in biopsy sample
Necrotic cells, partially necrotic hematopoietic cells, bone
*Sufficient tissue sample

Case 1

Staging was completed with Tc99m-DPD bone scan

Uptake seen in S1 and S2 (new), T4, T7-8, and some ribs

Second biopsy on S1 and S2

BUT no malignant cells AGAIN in the biopsy sample

Biopsy of L4 → no evidence of malignancy

Histological assessment MANDATORY considering:
  2 different carcinomas in patient’s history
  Different chemotherapy regimen options pending

Case 1

FDG-PET/CT scan for further biopsy planning

Multiple FDG-avid bone lesions, incl. proximal R humerus, lateral L clavicle, scapulae, ribs, several vertebral bodies, proximal femoral bones
* C7, T9-L3 (shown)
Liver lesion
Inguinal lymph node

Max SUV 14.1, Min SUV 2.5

Previous biopsy sites (T7, S1, S2) only showed faint or no FDG uptake; L4 biopsy site just lateral to FDG-avid area

Case 1

L3 very high FDG uptake → site for yet another biopsy

Retrospective fusion of post-biopsy CT and pre-biopsy PET data to plan biopsy trajectory
   Can see that this time, the biopsy needle traversed the FDG-avid area in L3

Pathology: small cell carcinoma NOT related to either of the previous 2 cancers (prostate, bladder)

Diagnosis: a tertiary carcinoma (a 3rd malignancy – neuroendocrine small cell cancer) as the origin of the bone mets

Carboplatin/etopside chemo → remission

PET/CT Guided Interventions

A Brief Mention of PET/CT Guided Radiation Therapy
Radiation Therapy Planning

Radiation therapy is an important cancer treatment modality, and uses high targeted doses of radiation to destroy malignant cells by damaging their DNA

- Permanently destroy cancer cells & minimize damage to surrounding healthy and normal tissue

- A patient’s radiation therapy plan is developed based on:
  - Type, size, location, and depth of the cancer relative to normal tissue
  - General health and medical history of the patient
  - Any adjuvant therapies
  - Therapy delivery technique → IGRT*

- Planning begins with simulation → PET/CT guidance can play a role in IGRT
IGRT & PET/CT

Repeated period imaging during treatment

Software to assess tumor size and location before and after Tx

Applicable adjustments made to radiation therapy dose and/or positioning

Improved accuracy

Monitor treatment progress

Colorectal liver metastasis on FDG-PET/CT before and after ablation therapy shows accuracy of PET/CT guided radiation therapy

PET/CT Guided Interventions

3 Future Prospects
Future Prospects

Cost-effectiveness and affordability of PET/CT
- High annual operating costs
- Healthcare budget cuts or freezes → affordability? ROI? Sustainable? (Health Econometrics)

Access to PET/CT
- Provincial programs
- Limited number of scanners Canada-wide

The future of PET/CT guided interventions
- Opportunity costs, Health Canada approval?
- Medical benefits don’t always mean economic benefit
- Importance of champions
Conclusion

1) PET/CT Guided Biopsies
   - A possible solution for addressing limitations of biopsies
   - 2 techniques: retrospective and intra-procedural (real-time)
   - Potential for value added management
   - Challenges

2) PET/CT Guided Radiation Tx
   - IGRT → more value in treatment monitoring?

3) Potential Future Prospects
   - Complicated
   - Uncertain outlook in Canada
Thank You

Questions