Polarimetric Imaging for Uterine Cervical Cancer Diagnosis

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To Set the stage....

Why Cervical Cancer

- 2nd women cancer (after breast) by mortality, 275,000 deaths/yr essentially in developing and emerging countries
- Screening + Disease Management Procedures implemented in developed countries are very efficient but still perfectible (80% decrease in mortality)
- Situation is very different in emerging countries
- Cervix is accessible for direct (non endoscopic) imaging and good physical model.
- We met highly competent and motivated gynecologists

Our Goals

- To develop an optical diagnostic tool to be used in real life
- To make good science on real life objects and bring a solution to human issues

Polarimetric Imaging

- Can be added to virtually any optical system at affordable cost
- Should be easily accepted by practitioners
The Uterine Cervix

• Outline of anatomy and physiology
• Cancer onset and evolution
• Current screening and disease management

Polarimetric imaging

• Orthogonal State Contrast (OSC) imaging in-vivo
• Full Mueller imaging ex-vivo

Conclusion and Outlook
Anatomy and Physiology – Outline

I – Uterine Cervix
Anatomy outline
Cancer onset
Screening and Disease management

II – Polarimetry
OSC
Mueller

III – Conclusions

Female Reproductive System

Endocervical channel

Endocervical channel

Fallopian tube
Ovary
Exocervix
Cervix
Uterus
Vagina

Glandular Epithelium (endometrium)

Junction zone

Malphighian epithelium

Uterine Cervix

Polarimetric Instrumentation Group
Microscopic Structure of Epithelia

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Mature Malpighian epithelium

- Basal layer
- Intermediate layer
- Superficial layer

Glandular epithelium (endometrium)
One or two cell layers (tens of µm)

300 µm
Structure of the Junction Zone

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- Malpighian
- Glandular

Stroma or Chorion (connective tissue)
Crypt (glandular tissue)
Infection by Human Papilloma Virus. Common virus eliminated by the immune system

Cervical Intraepithelial Neoplasia (CIN)

- Very slow evolution (5 to 10 years from infection to invasive cancer)
- Easily cured by simple surgery (conisation)

Screening is very effective but not perfect (reduction of mortality by 70-80%)
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Anomalous Pap smear → Colposcopy → Biopsy of suspect zones

Pathology analysis: final diagnosis

Colposcopy: Precancerous (CIN2+) lesions are very difficult to visualize. Results are very operator dependent.

Conization: the surgical margins are poorly defined

Systematic Pap smear cannot be implemented in developing countries. Currently no alternative is available to reduce the death toll (275 000 per year worldwide)
Polarimetry Experiments

I - Orthogonal State Contrast (OSC)
Colposcopy

I – Uterine Cervix
- Anatomical outline
- Cancer onset
- Screening and disease management

II – Polarimetry
- OSC
- Mueller

III – Conclusions

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Orthogonal States Contrast

\[ I_{OSC}(\alpha) = \frac{I_{\|} - I_{\perp}}{I_{\|} + I_{\perp}} \]

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Polarizer
LC + Polarizer

Polarizer
LC + Polarizer
Colposcopy Azimuth

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Colposcopy

Pathological cervix

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- OSC
- Mueller

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Polarimetry Experiments

II – Mueller Images on ex-vivo tissues
Description de la polarimétrie

Application ex-vivo : Tissu biologique (conisation)

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Retardation

Depolarization

Anatomopathologist Cartograph

Ectropion
Dysplasia
Healthy
Ex-vivo Mueller Images – Healthy sample

Lu Chipman decomposition

\( \Delta \): depolarization, \( R \): retardation, \( \alpha \): orientation of slow axis

Observation direction

C: Cervix, MT: Myometrium

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Ex-vivo Mueller Images – Healthy sample + CIN1

Lu Chipman decomposition
\[ \Delta : \text{depolarization}, \quad R : \text{retardation}, \quad \alpha : \text{orientation of slow axis} \]

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Observation direction

2cm

C
MT

Healthy

CIN 1

\[ \Delta \]

\[ R \]

\[ \alpha \]

0° 25° 50°

0° 90° 180°
Ex-vivo Mueller Images – Healthy + CIN3 + Glandular

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Colposcopy

Pathology

To observer
Ex-vivo Mueller Images – Healthy + CIN3 + Glandular

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To observer
Summary of Observed Trends

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• Healthy malpighian epithelium exhibits a specific birefringence.

• Birefringence disappears already at stage CIN1. This birefringence is more specific than classical colposcopy.

• Depolarization « hierarchy »: glandular < CIN3 < CIN1 < healthy malpighian.

• Multiwavelength imaging should be able to disentangle contributions from deep structures (crypts).

![Graphs showing retardance and depolarization](image_url)
What comes next….

- Project « PAIR Gynéco » funded by the French Institute of Cancer (INCa)
  - Systematic study on 100 to 200 conizations, with learning and testing phases of image segmentation procedures (IMM & CHU de Bicêtre)
  - Assessment in vivo with a Mueller colposcope (CHU de Bicêtre)
  - Evaluation of polarimetry for the follow-up of radiochemotherapy for locally advanced cervical cancers (Institut Gustave Roussy)

- Polarimetric imaging of histological slides, modelling of polarized light scattering and, perhaps, understanding something about the observed contrasts
Thank you

**Physicians - Medical Team**

André Nazac – KB
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Pierre Validire – IMM
Henri Cohen – IMM

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