Caractérisation in vivo et ex vivo du comportement mécanique d'artères humaines : application à la conception des endoprothèses aortiques

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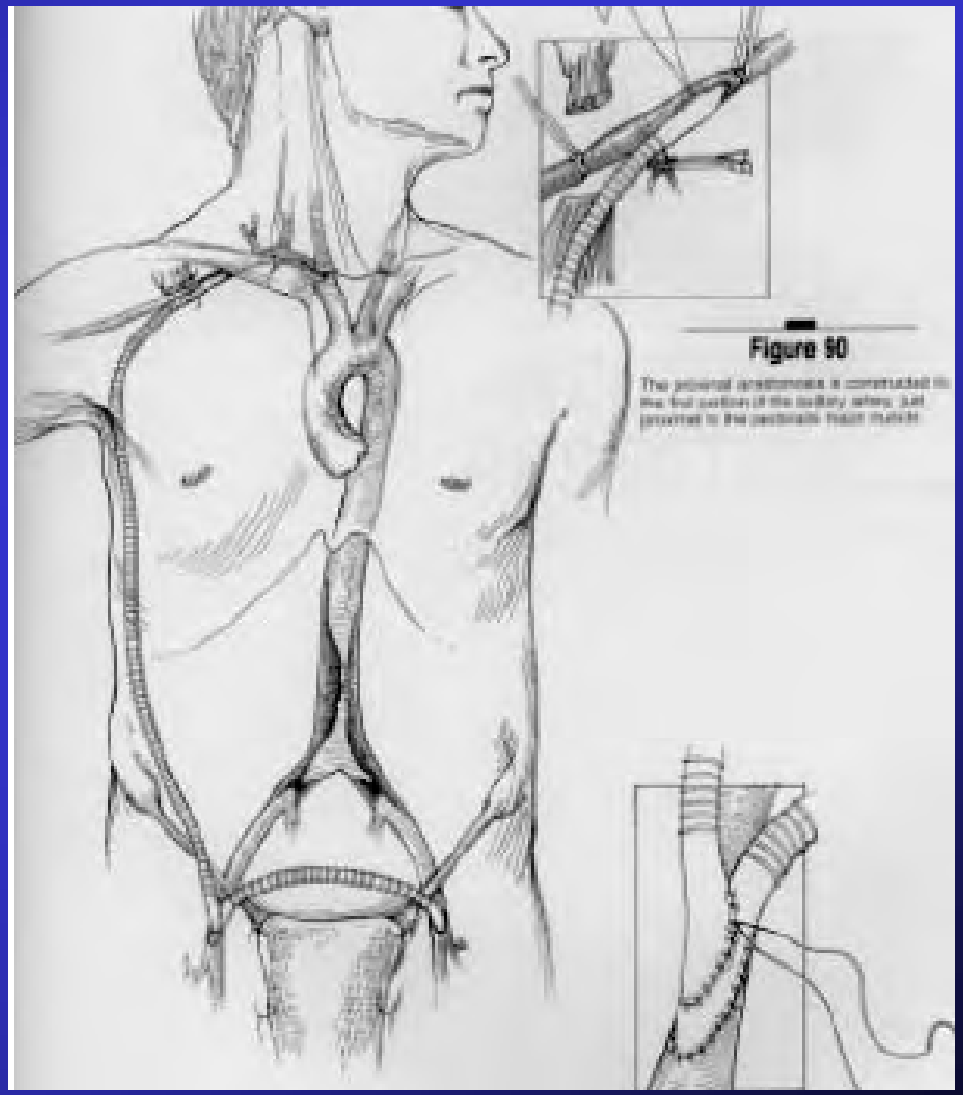
POURQUOI ?

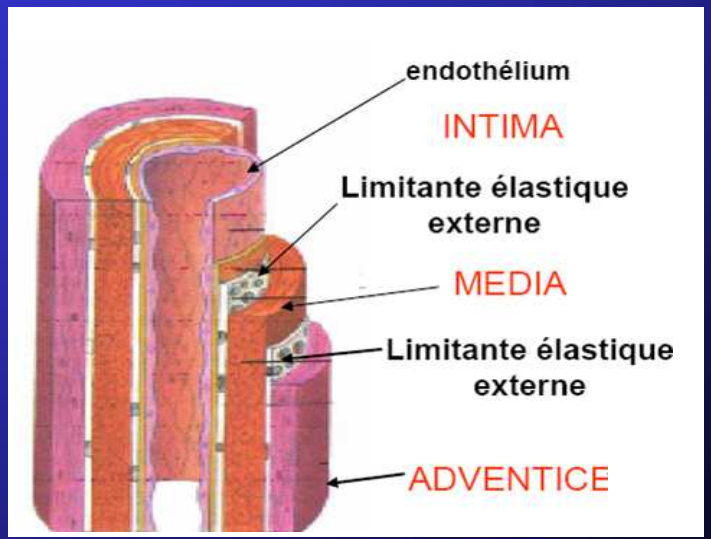
1. Diagnostics de lésions

2. Implantation de traitements

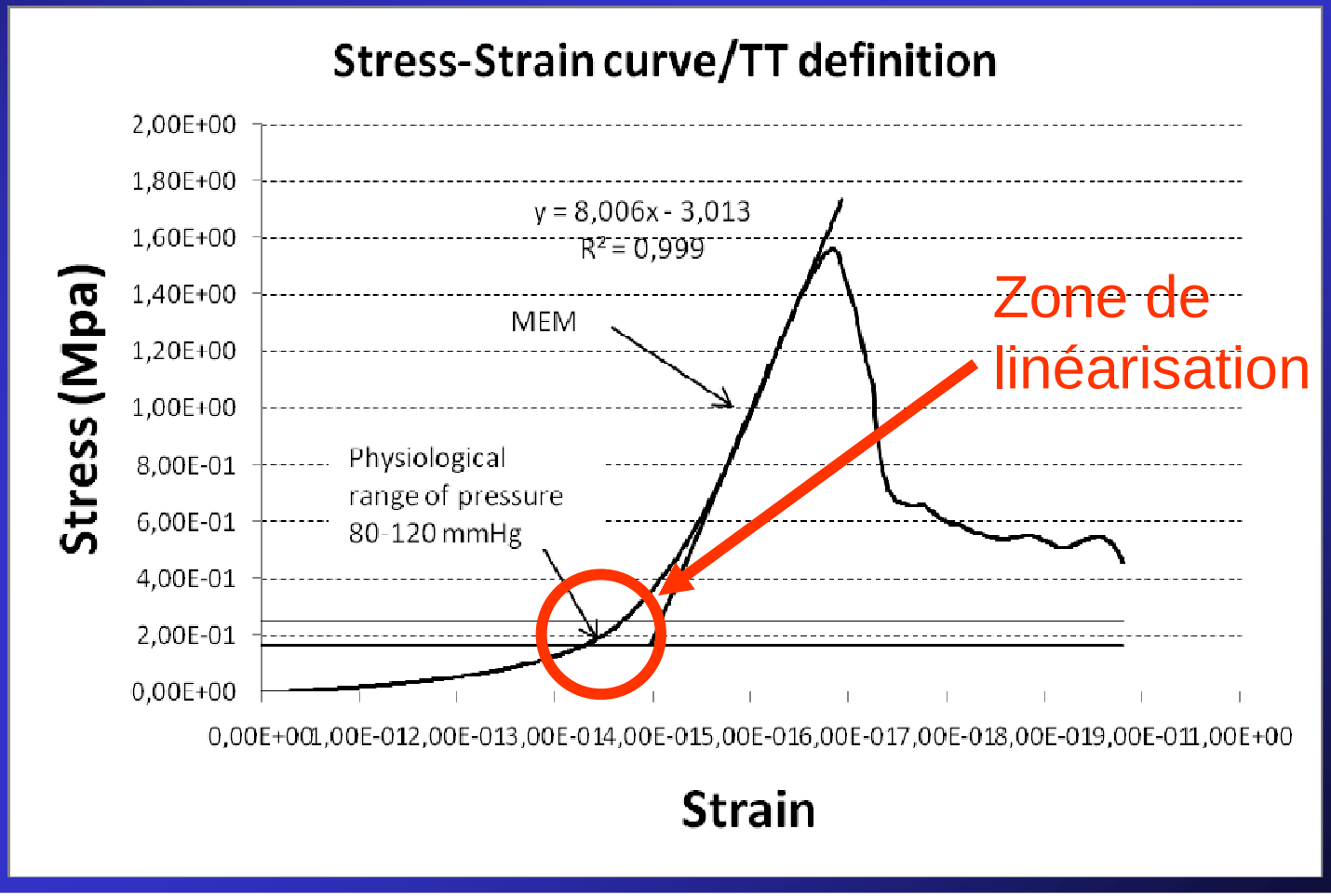


COMMENT CARACTERISER LE COMPORTEMENT MECANIQUE DES ARTERES HUMAINES...

1. essais « in vivo » …

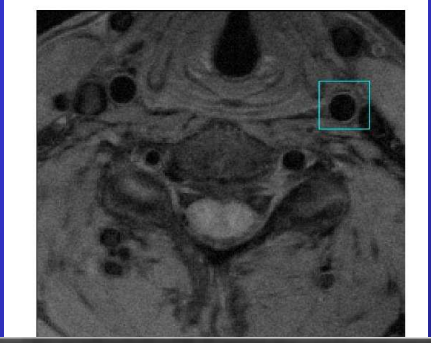


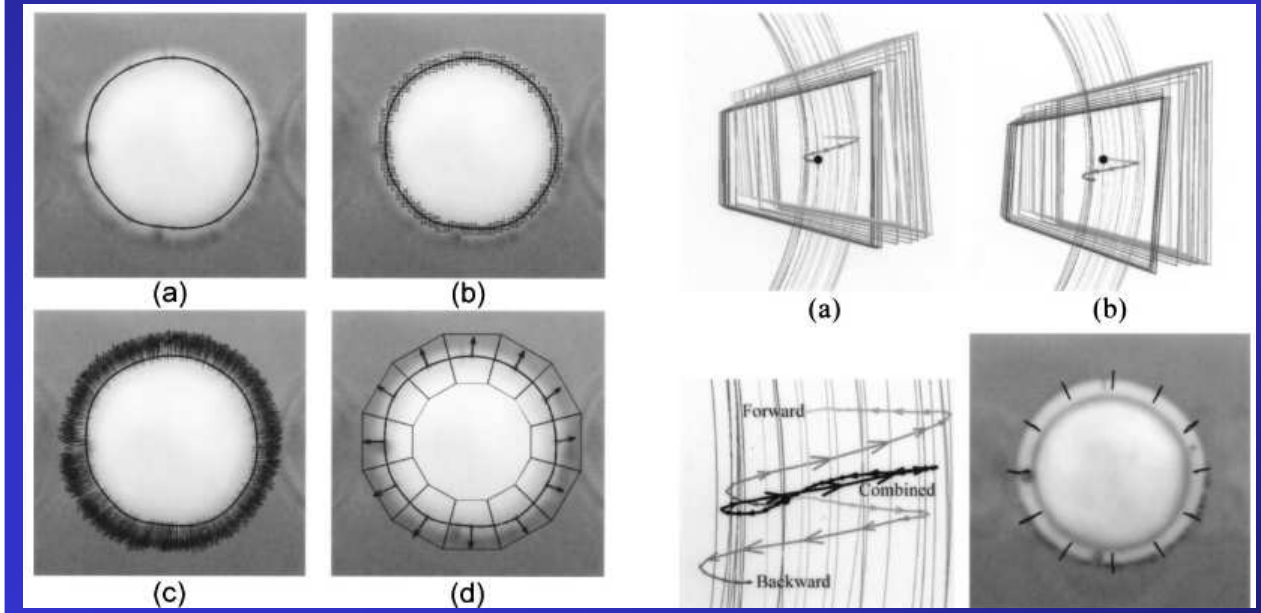
Utilisation du modèle élastique linéaire



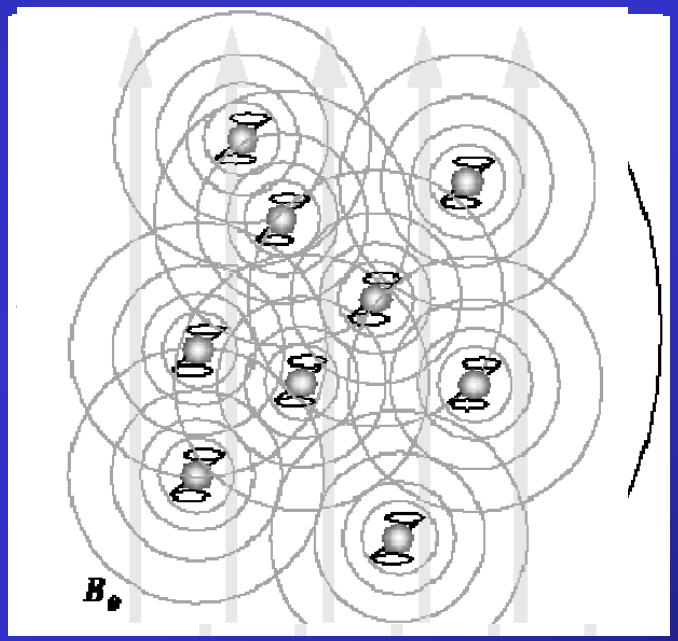
Mesures cinématiques par imagerie médicale

Exemple avec l'imagerie par résonance magnétique.





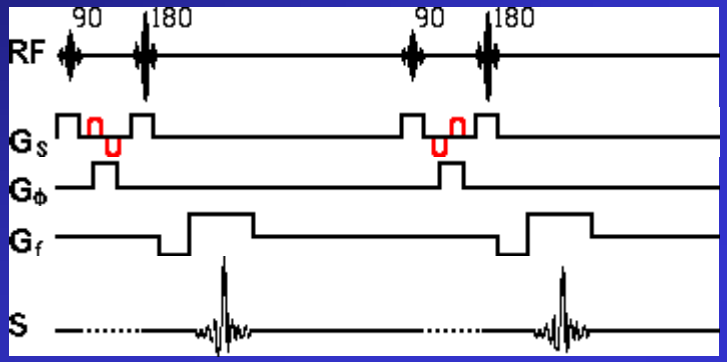
Basic principle of MRI

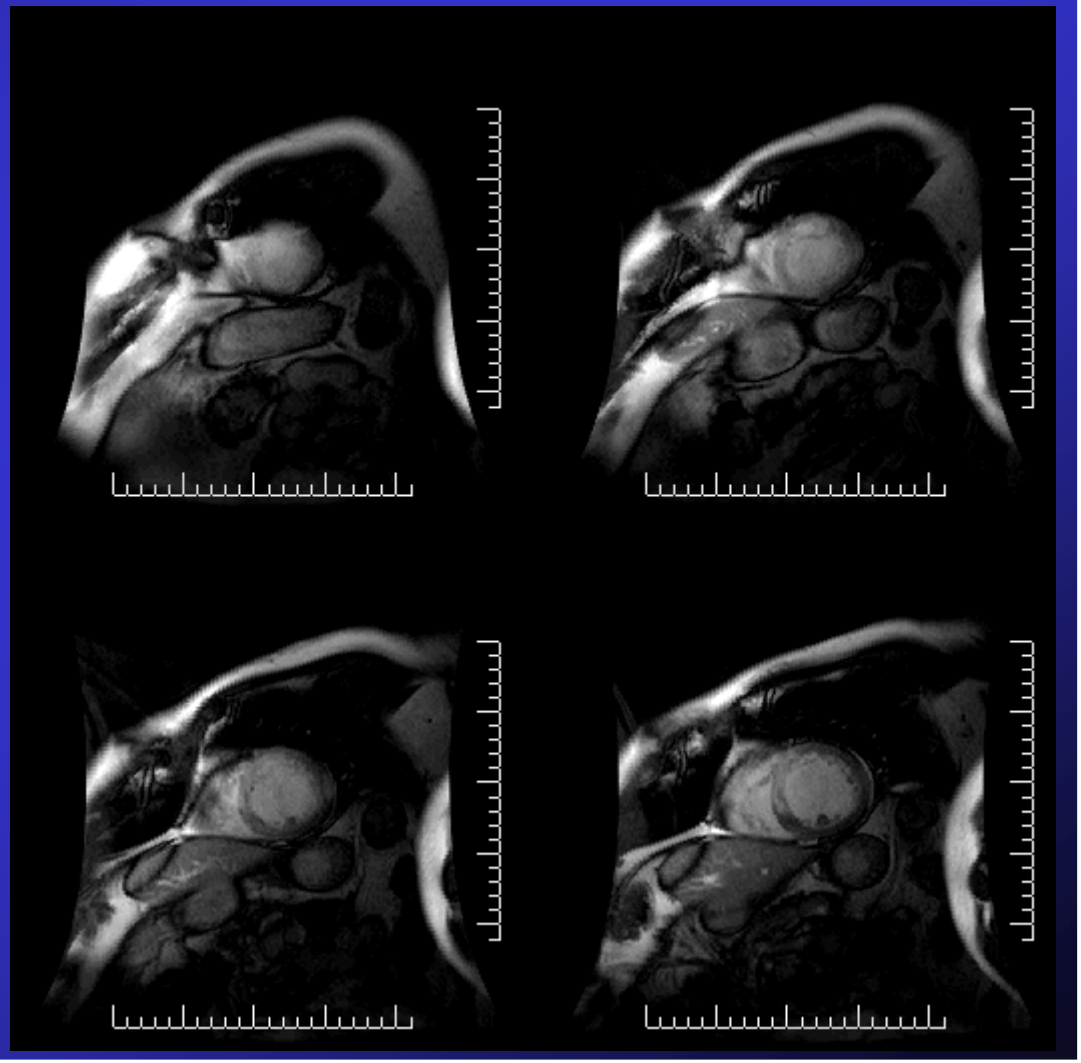


Use of gradients for encoding the different directions (frequency and phase encoding).

The voxel intensity of a given tissue type (i.e. white matter vs grey matter) depends on the proton density of the tissue and two other tissue-specific parameters: the longitudinal relaxation time T1, and the transverse relaxation time, T2.

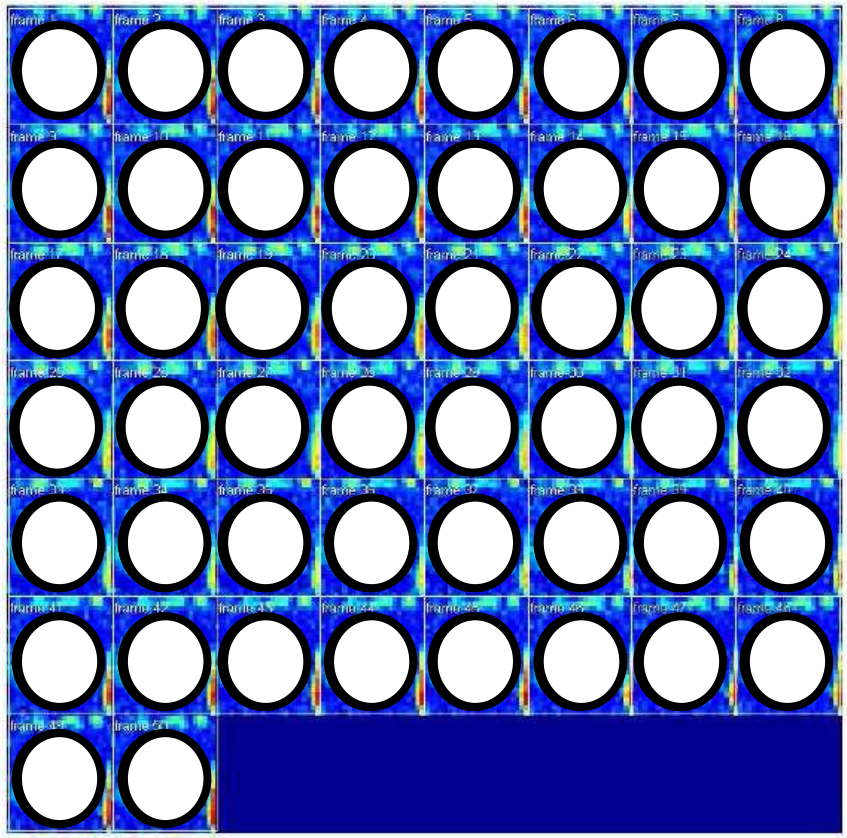
Principle of time resolved MRI



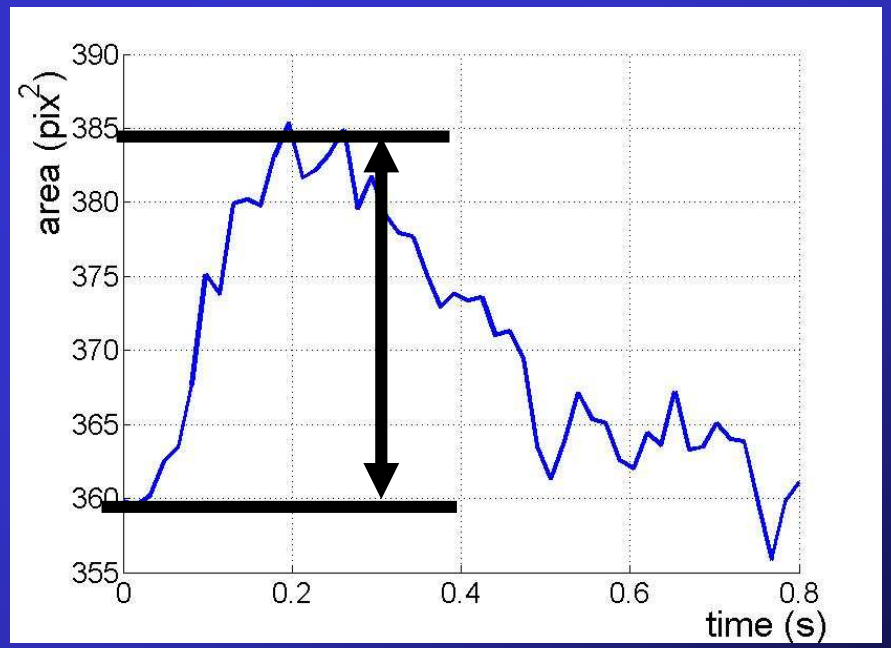


Cardiac-MRI-gating for synchronizing the MRI sequence and the ECG

Time resolved PC-MRI applied to the cross section of a patient's neck: signal magnitude



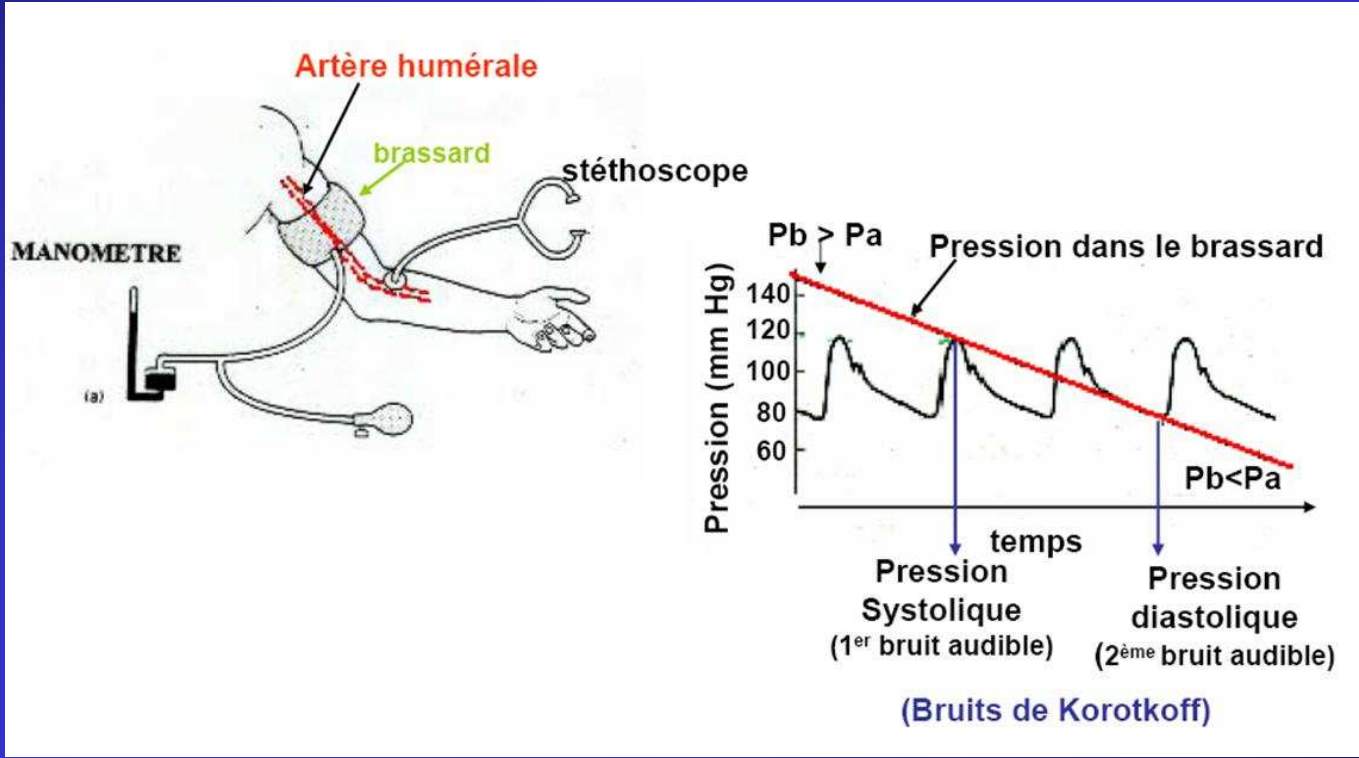
(b) Frames of signal magnitude



$\varepsilon = dR/R_0 = dA/2A_0 = 0{,}035$

Mesure des variations de pression

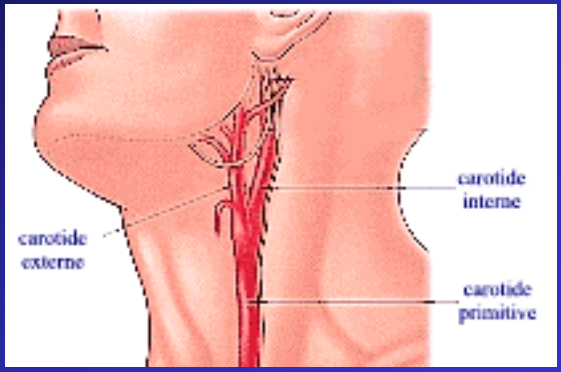
Le plus simple :

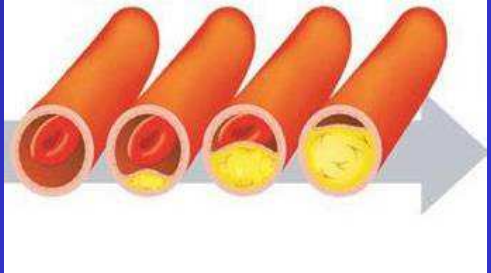


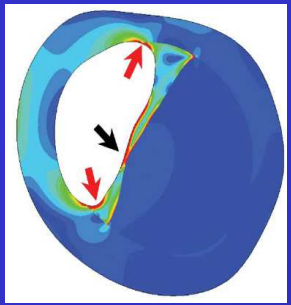
$$\sigma = p\, R_0/e = 40\times0{,}13\times5/0.6 = 43{,}3 \text{ kPa}$$

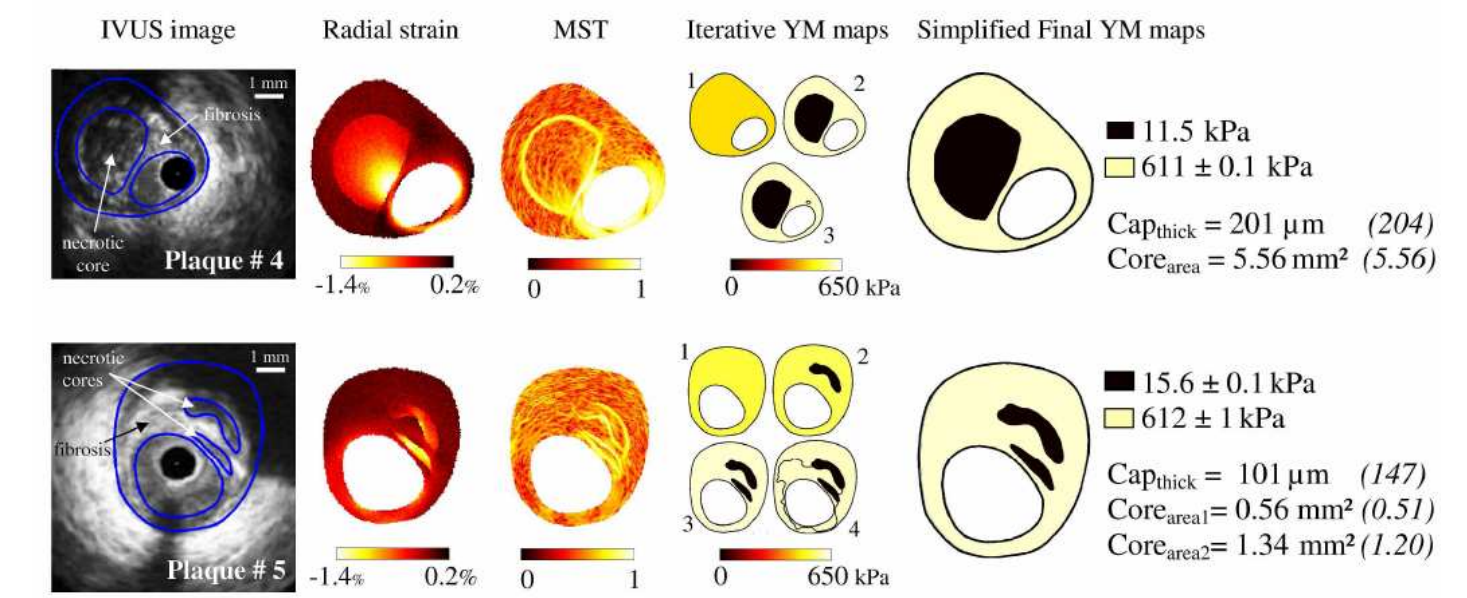
$$\mathbf{E = \sigma / \varepsilon = 1{,}2 \text{ MPa}}$$

Extension aux plaques d'athérome

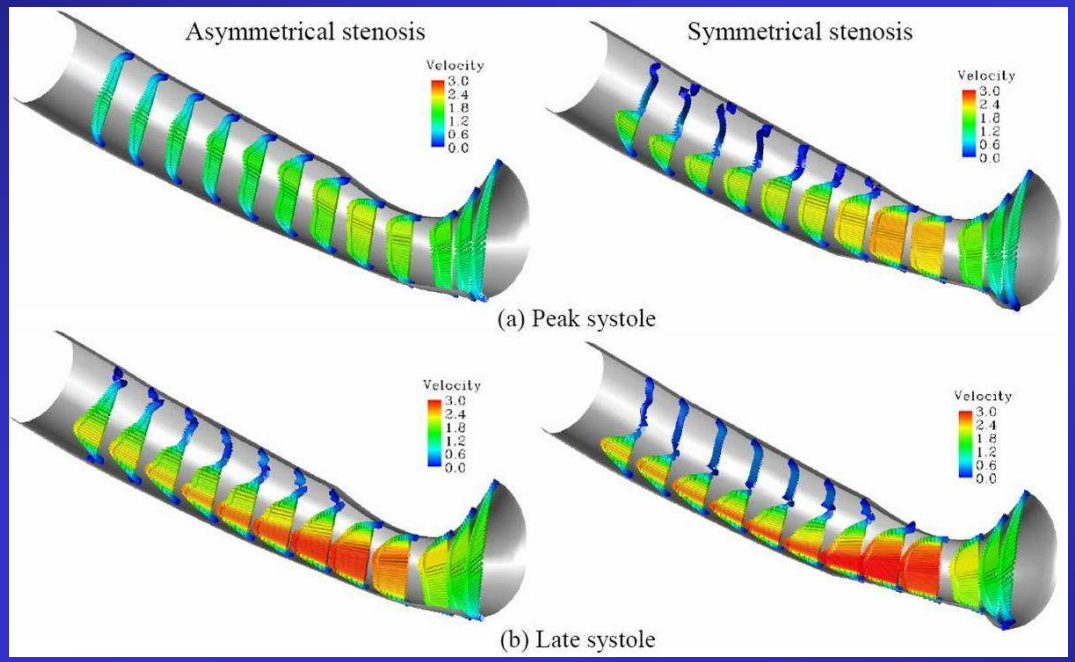




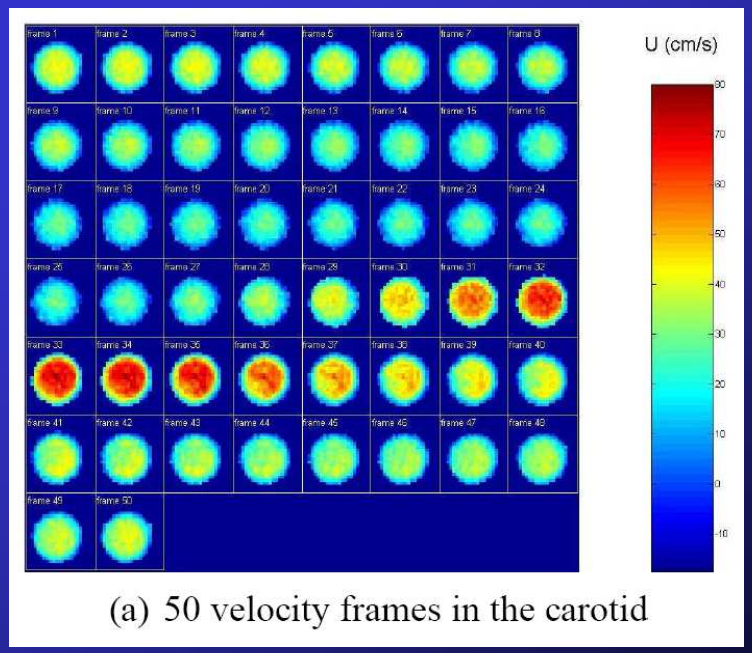




Recalage de modèles avec prise en compte des interactions fluide structure



FE model



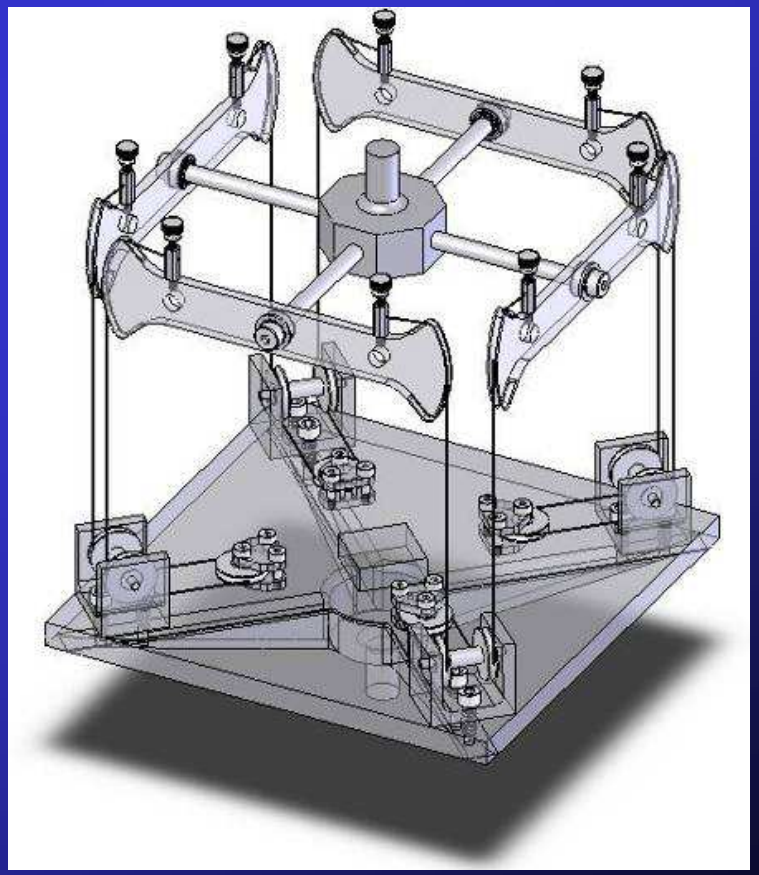
MRI measurement

LIMITES DES ESSAIS IN VIVO :

- Moyens de chargement limités
- Faible plage de déformations possibles
- Méthodes de mesures incertaines

→ Nécessité d'essais ex vivo …

ESSAIS EX VIVO CLASSIQUES



Les essais plans sont difficiles à exploiter

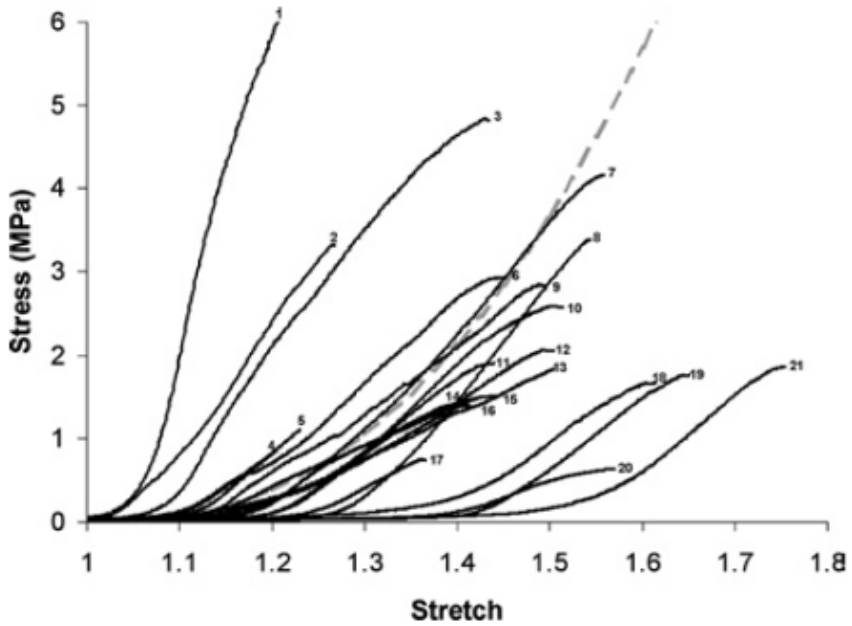


FIGURE 6. The uniaxial stress–stretch data for the porcine coronary arterial tissue and the regression curve fit to the average stiffness, curve fitted to specimen 7 (dashed line).

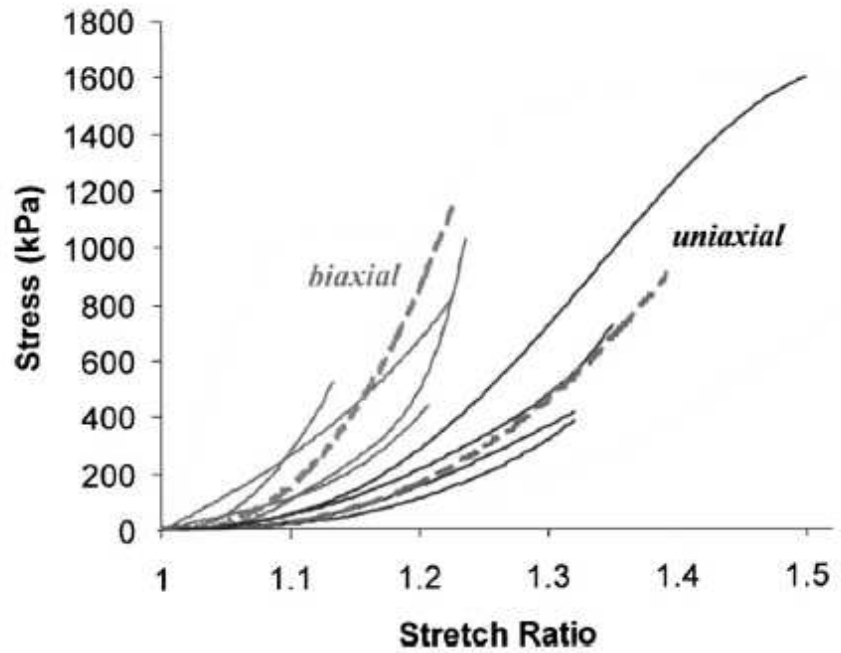
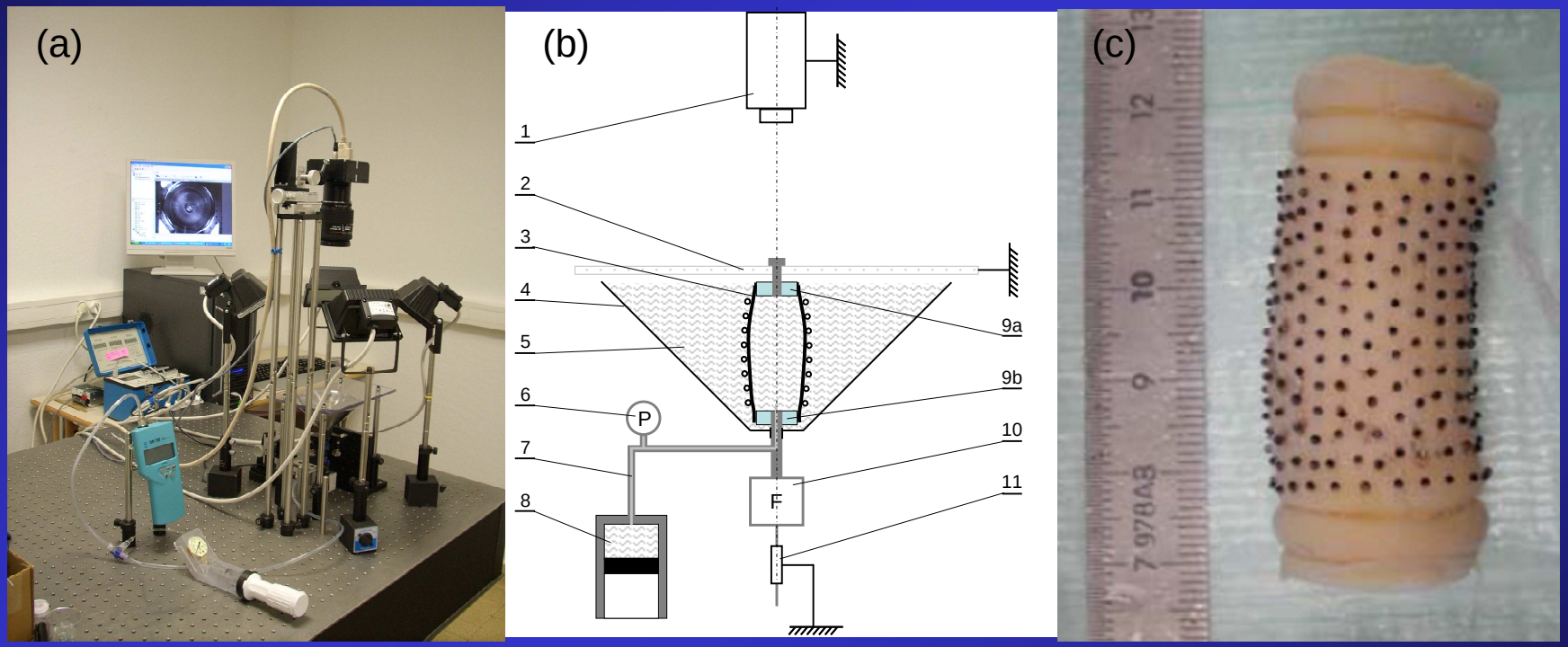


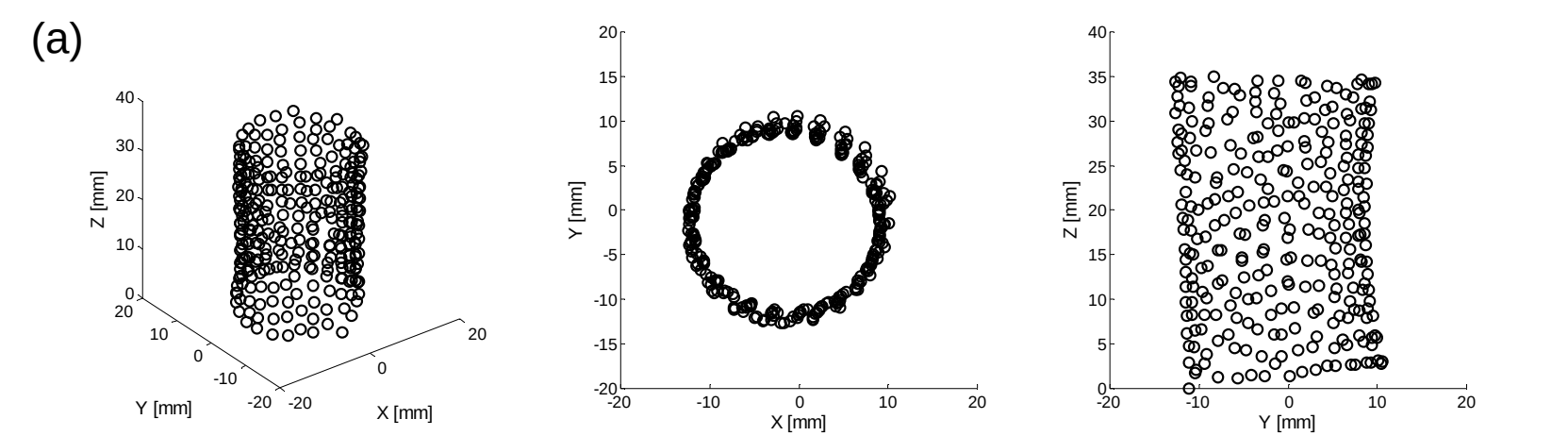
Fig. 7 Uniaxial and biaxial data for the human femoral artery, with the fitted biaxial and uniaxial constitutive models (dashed line)

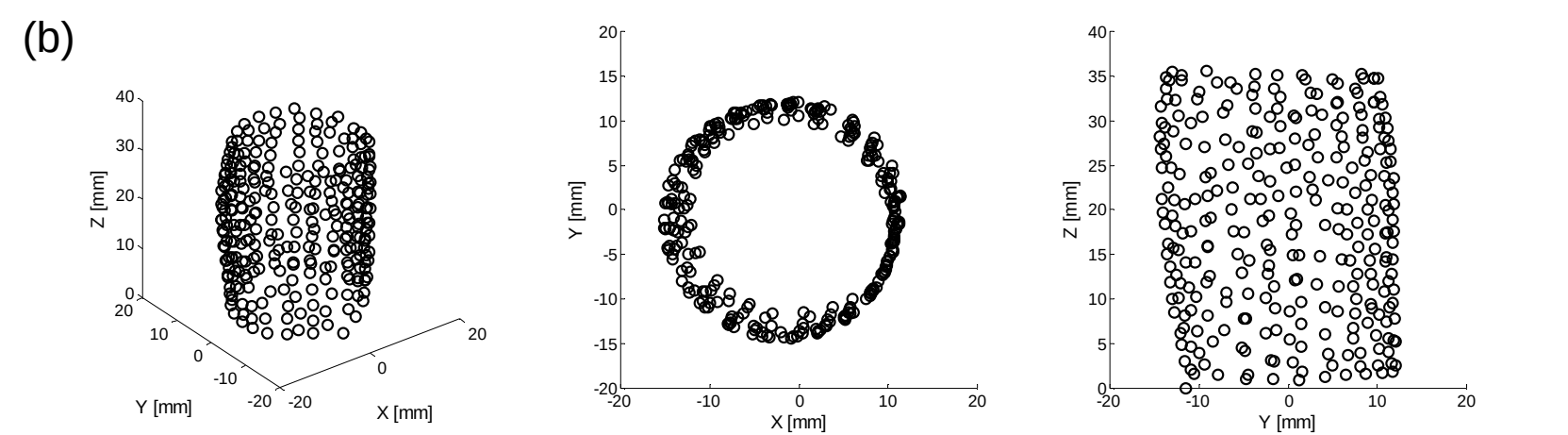
NOUVEAU PROTOCOLE D'ESSAI



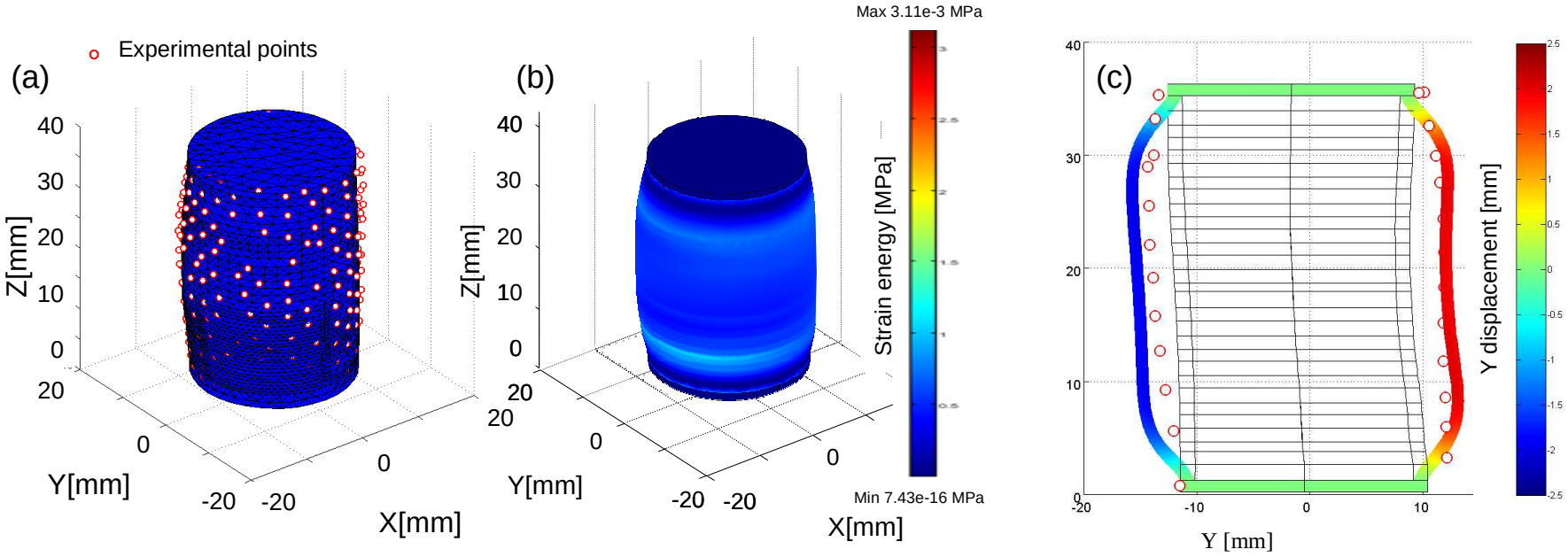
1. Caméra, 2. Plaque support en PMMA,
3.Artère, 4. Miroir conique, 5. Liquide physiologique,
6. Manomètre, 7. Canule, 8. Seringue,
9. Adapteurs, 10. Cellule de force,
11. Platine de translation

MESURE OPTIQUE DES DEPLACEMENTS

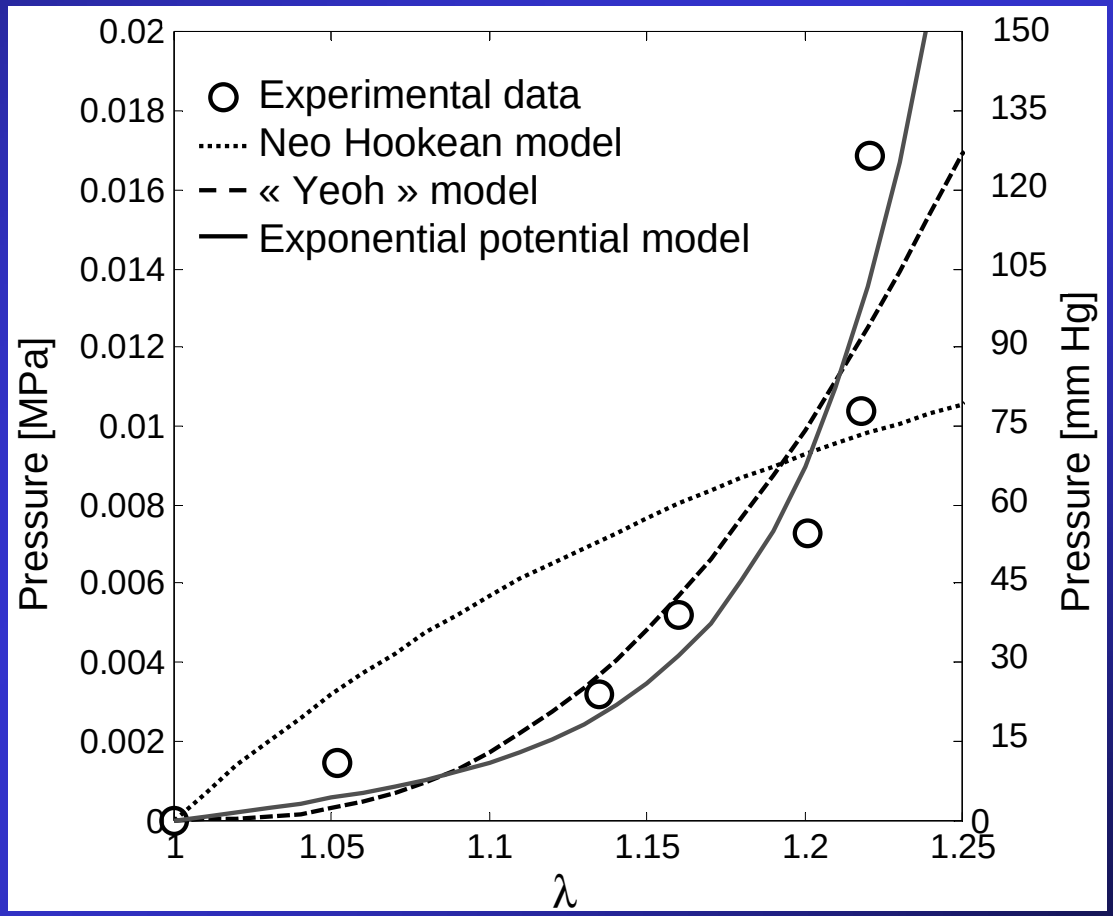




IDENTIFICATION PAR RECALAGE ELEMENTS FINIS

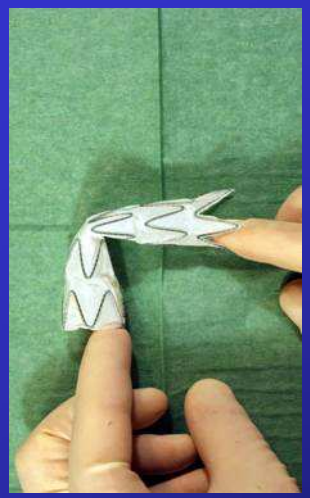


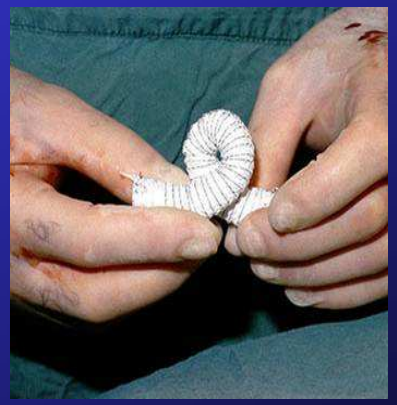
Exemples de résultats



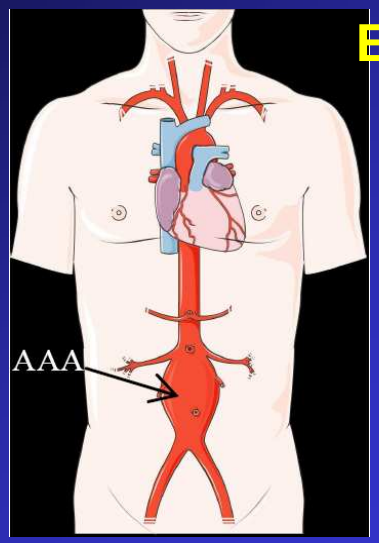
Application

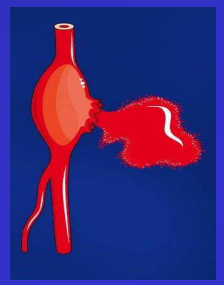
Optimisation de la microstructure des endoprothèses aortiques en vue d'une meilleure durabilité

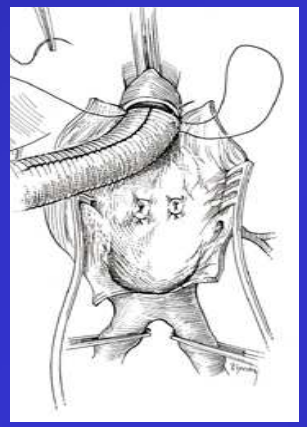


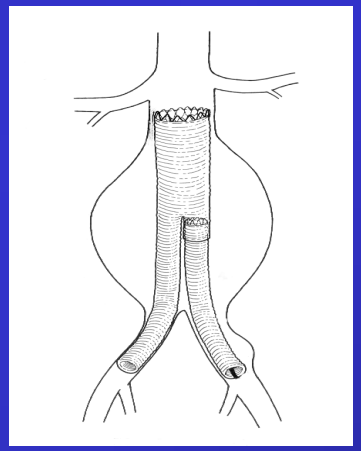


Anévrysmes de l'aorte abdominale = Enjeux majeurs de santé publique

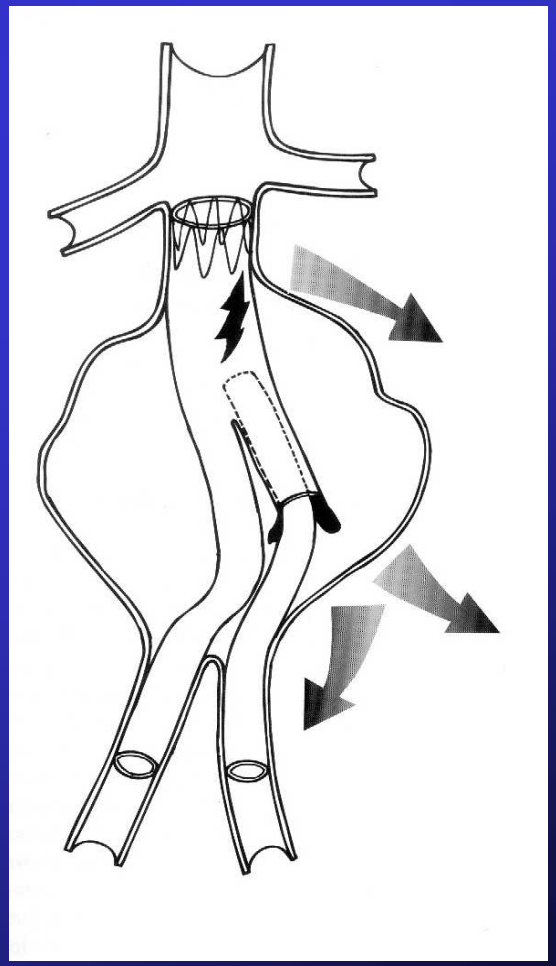


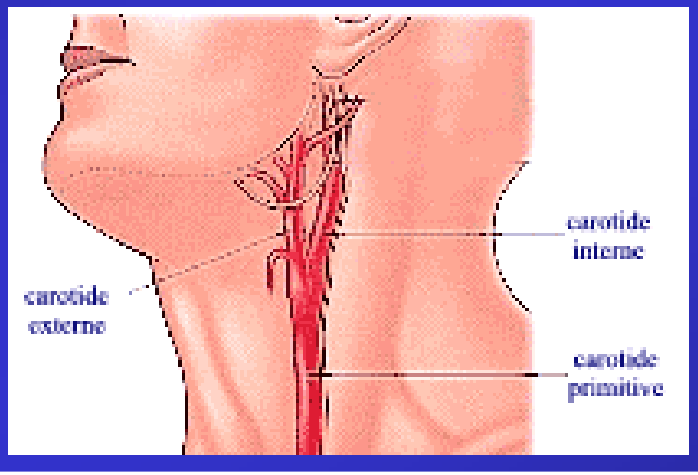
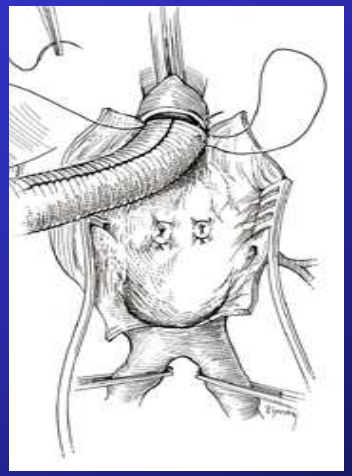
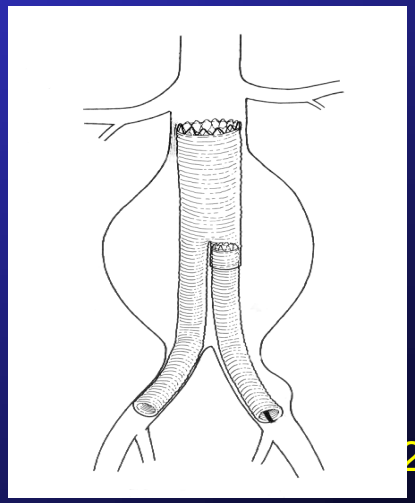






Les problèmes de durabilité des endoprothèses ont des origines essentiellement mécaniques.



CONCLUSION

- Comportement mécanique des artères complexe à caractériser
- Hypothèses simplificatrices nécessaires
- Différentes méthodes selon les objectifs