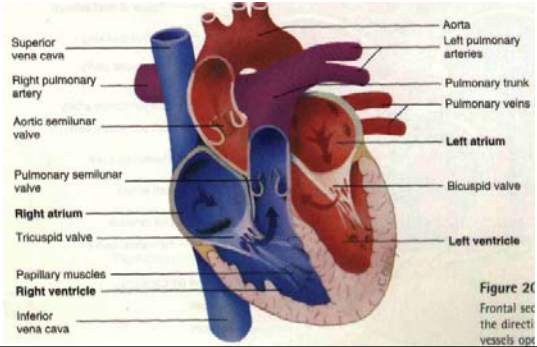
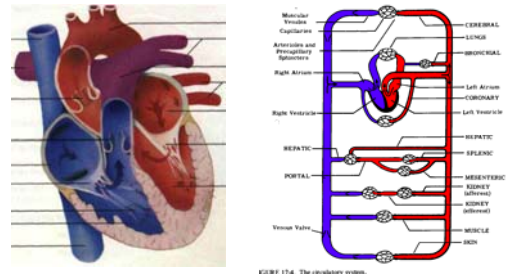


Hjertet som pumpe



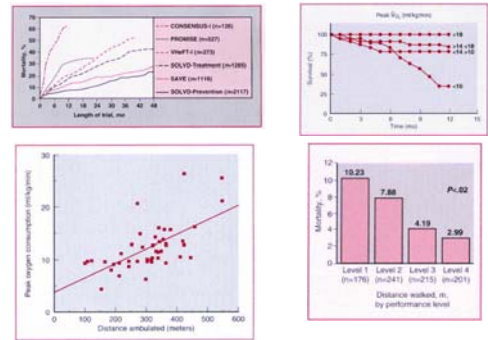
Sirkulasjonen:



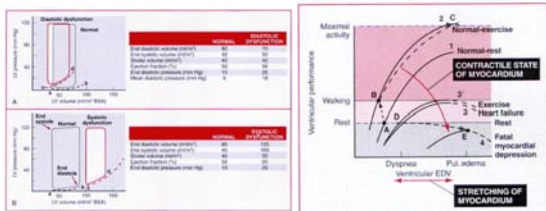
Hjertesvikt

- Akutt / Kronisk
- Backward (stuvning) / Forward (fall i CO)
- Høyresidig / Venstresidig
- Systolisk / Diastolisk

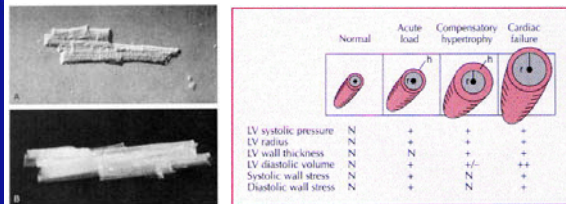
Hjertesvikt - prognose



Hjertesvikt patofysiologi



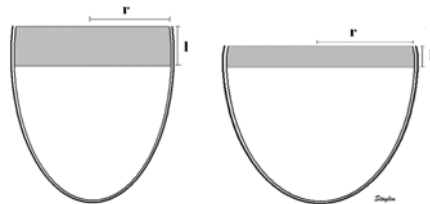
Hypertrofi:



Hypertrofi:

- Patologisk hypertrofi: permanent overbelastning
 - klaffefeil, hjertesvikt
- Redusert kontraktilitet
- Fysiologisk hypertrofi: Treningseffekt (kortvarig overbelastning med reparasjon under hvile)
- Økt kontraktilitet

Betydningen av dilatasjon:



Nøkkelord:

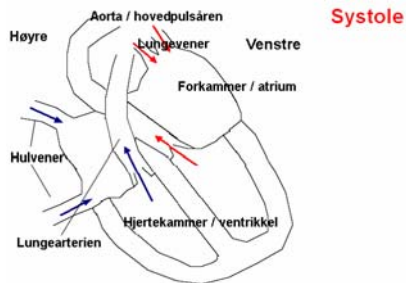
- Endediastolisk volum: EDV
- Endesystolisk volum: ESV
- Slagvolum: $SV = EDV - ESV$
- Hjerterefrekvens: HR (Heart Rate)
- Minuttvolum: $CO = SV \times HR$
- Ejeksjonsfraksjon: $EF = SV / EDV$

Hvordan måle hjertefunksjon?

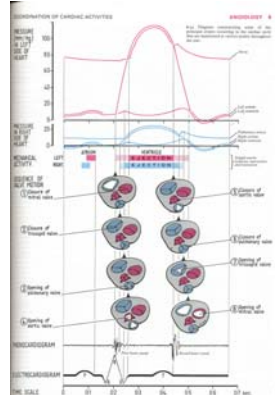
- Kandidater:
 - CO
 - SV
 - EF
- (Kontr. Hastighet)
- Komp. Mekanismer:
 - $\downarrow SV$ og $\uparrow HR$
 - $\uparrow EDV$ og $\downarrow EF$
 - $\downarrow Load$ og $\uparrow E$ jeksjonstid

Men fortsatt bare systolisk funksjon!

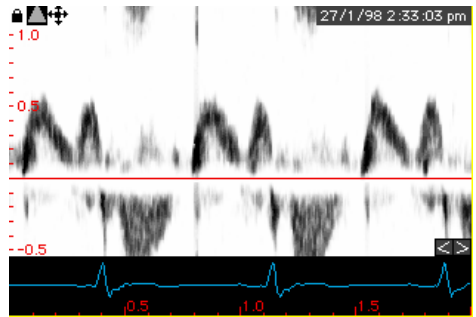
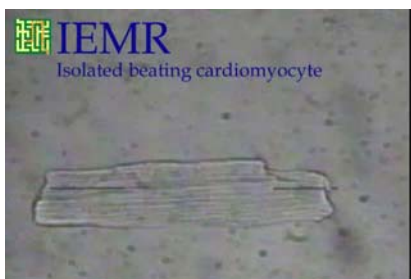
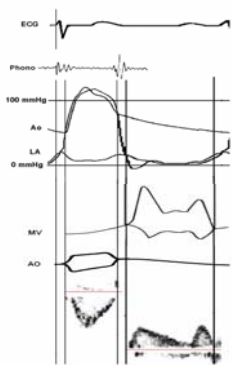
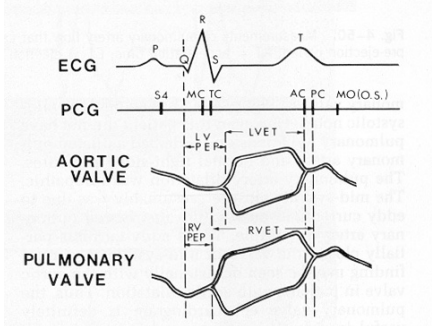
Hjertet som pumpe



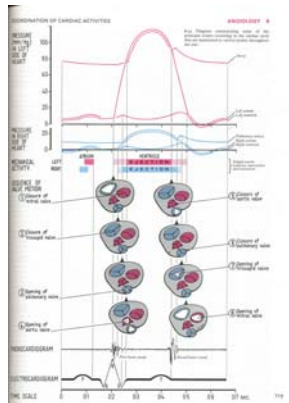
Hjertesyklus:



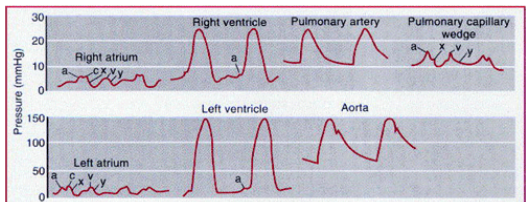
Timing:



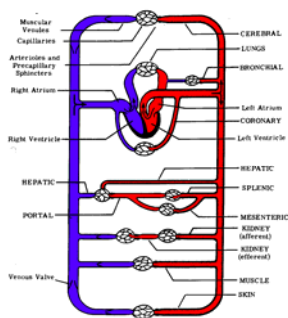
Hjertesyklus:



Trykkurver:

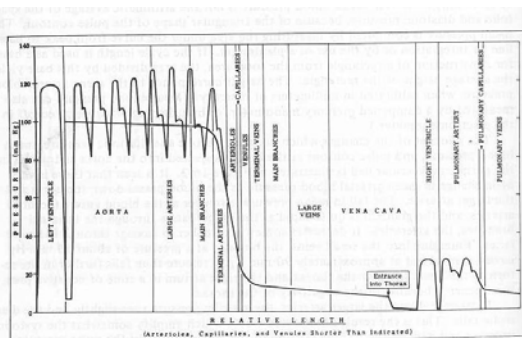


Sirkulasjonen.



19 GIBRF 174. The circulatory system.

Trykkfallet i sirkulasjonssystemet



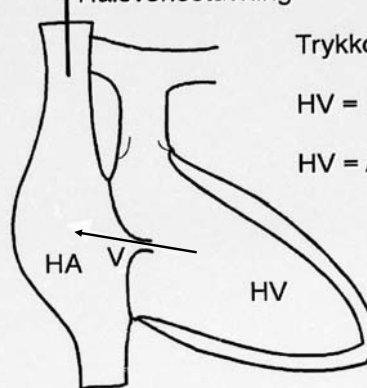
20

Prinsipp for trykkestimering

- Kvantitative metoder
 - Gradientmåling mellom to kammer: Kjenner en trykket i det ene kammeret, kan en beregne trykket i det andre
- Semikvantitative metoder
 - Tidsintervaller, flowkarakteristika, bevegelsesmønster og formforandringer som indikerer trykknivå

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Halsvenestuvning

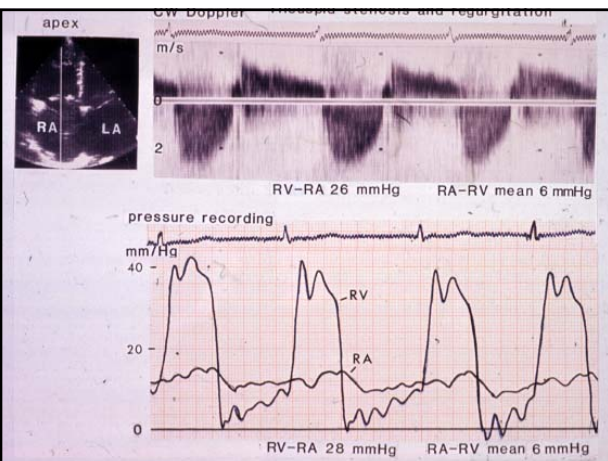


$$\text{Trykkdifferanse} = 4xv^2$$

$$HV = HA + 4xv^2$$

$$HV = AP$$

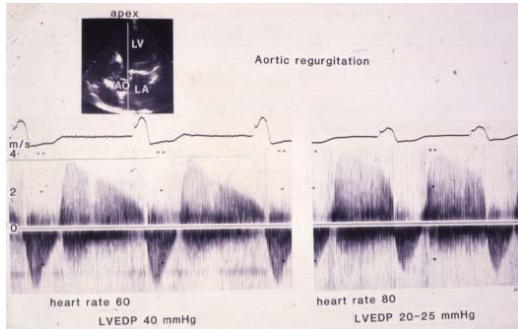
24



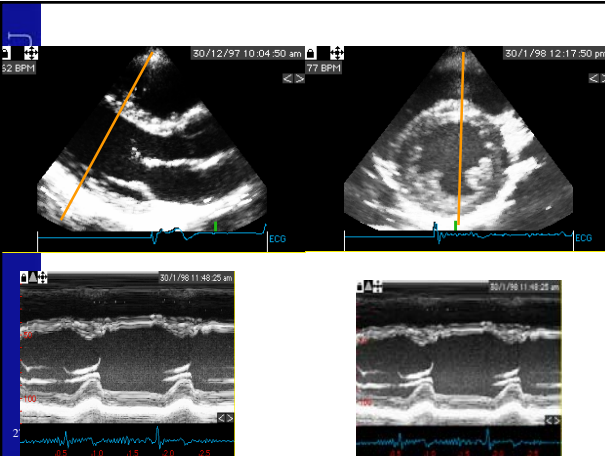
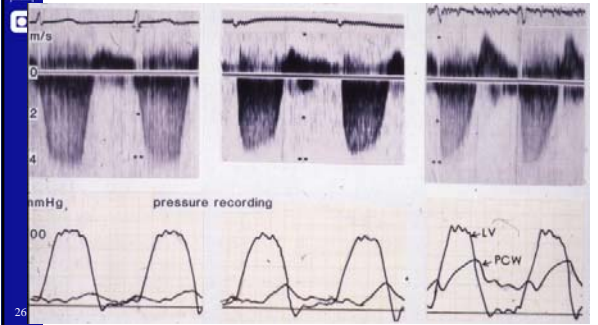
Hg-T ↓	Heart rate												SPAP				
	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	
0-010																	30 (25-35)
0-015																	35 (30-40)
0-020																	40 (35-45)
0-025																	45 (40-50)
0-030																	50 (45-55)
0-040																	55 (50-60)
0-045																	60 (55-65)
0-050																	65 (60-70)
0-055																	70 (65-75)
0-060																	75 (70-80)
0-065																	80 (75-85)
0-070																	85 (80-90)
0-075																	90 (85-95)
0-080																	95 (90-100)
0-085																	100 (95-105)
0-090																	105 (100-110)
0-095																	110 (105-115)
0-100																	115 (110-120)
0-105																	120 (115-125)
0-110																	
0-115																	
0-120																	
0-125																	
0-130																	
0-135																	
0-140																	
0-145																	
0-150																	
0-155																	
0-160																	
0-165																	
0-170																	
0-175																	

Burstin, 1961

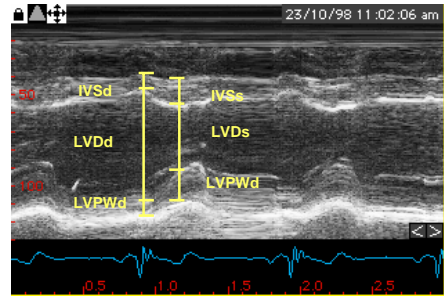
Aortainsuff. - enddiastolisk trykk



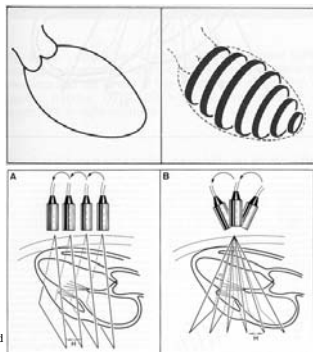
Indikasjon på V-bølge i v. atrium



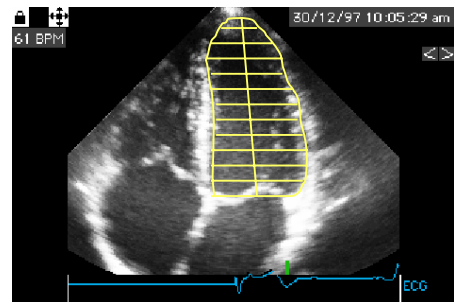
M-mode:



2D ekko – volumberegning:



Modifisert Simpson:



Ejeksjonsfraksjon:

Systole
 $SV = EDV - ESV$
 Normalt $> 45 \text{ ml / m}^2$

Diastole
 $EF = SV / EDV$
 Normalt $> 50\%$

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Svakheter:

- Endokarddefinisjon
- Dropouts
- Trabekler papillemuskler
- Tracing lite reproduserbar:
 - 20% inter og 6% intraobserver
- Alle diameterfeil opphøyes i 2

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Invasiv måling av minuttvolum – termodilusjon

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Invasiv måling av minuttvolum – Ficks prinsipp

Rate of indicator out = rate in + rate added
 $Q \times C_{out} = Q \times C_{in} + V$
 $Q = \frac{V}{(C_{out} - C_{in})}$
 When O_2 is used as indicator:
 $Q = \frac{VO_2}{C_a O_2 - C_v O_2}$

$VO_2 = CO * O_2\text{ekstraksjon}$
 $CO = VO_2 / O_2\text{ekstraksjon}$

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Doppler minuttvolum:

- Forutsetninger:
 - Sirkulær åpning
 - Flat flowprofil
 - Liten vinkel mellom blodstrøm og ultralydstrålen
 - Liten bevegelse av ostiet
- LVOT nærmest til dette

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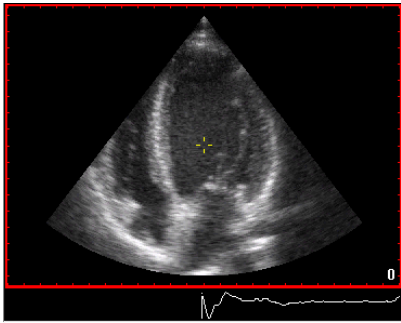
Prinsippet:

$A = \pi(d/2)^2$

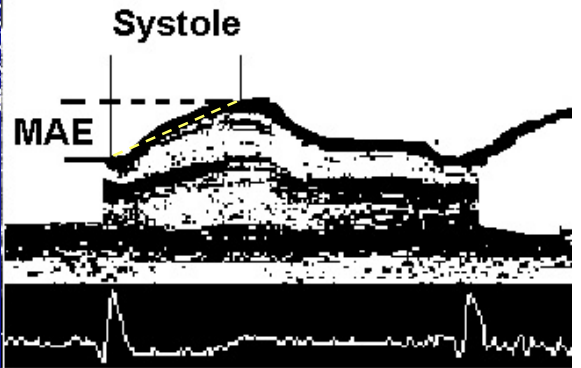
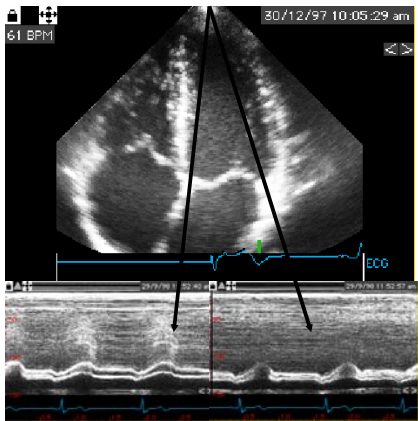
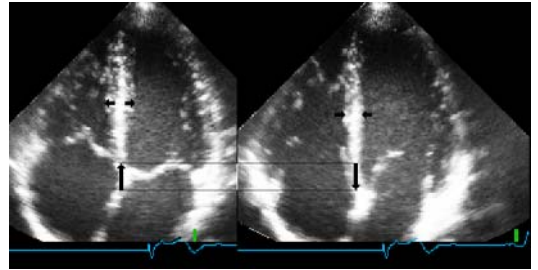
$V = s \times A$
 $SV = s \times A = \int v \, dt \times \pi(d/2)^2$
 $CO = SV \times HR = \int v \, dt \times \pi(d/2)^2 \times HR$

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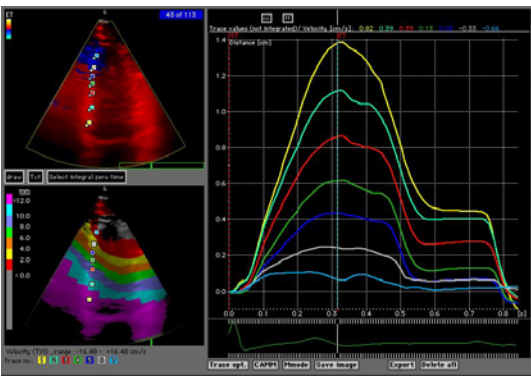
Langaksebevegelsen:



Langaksebevegelsen:



Tissue tracking:

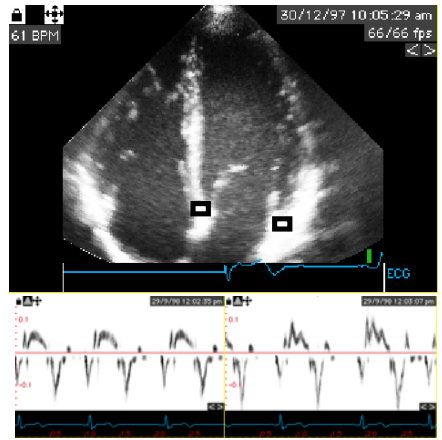
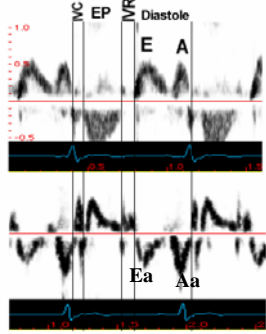


- MAE > 10 mm tilsvarer EF > 50%
- MAE < 7 mm Tilsvarer EF < 30%
- Korrelasjon MAE og EF 0,80

Alam et al 1992

Støylen et al 2003

Vevsdoppler og flow:



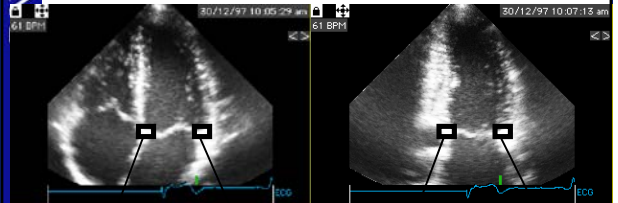
Normalverdier:

- Gulati et al 1996:
 - Peak velocity korelerer med EF: $R = 0.86$ (Støylen et al 2003: $R = 0.66$)
 - Peak velocity > 5,4 cm/s tilsvarer EF > 50%
- Vinereanu et al 2001:
 - Peak velocity > 9 differensierer mellom normal og patologisk hypertrofi (men alle med normal EF)
 - Normalverdi > 8

Normalverdiene gjelder gjennomsnitt av 4 punkter:

firkammer

tokammer



septalt

lateralt

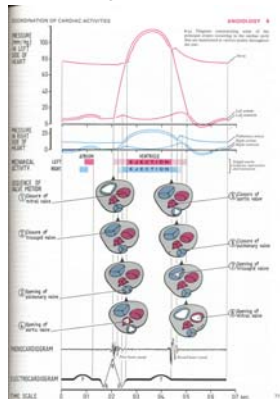
inferiort

anteriort

Gjennomsnittet av 4 punkter reduserer også variabiliteten med 25%

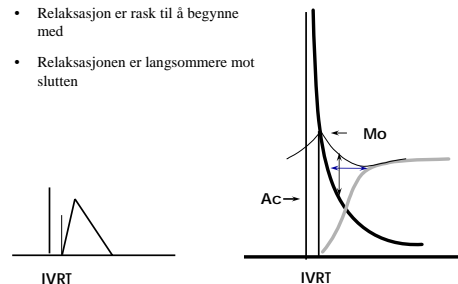
Støylen et al 2003

Diastolisk funksjon



Venstre ventrikel relaksasjon

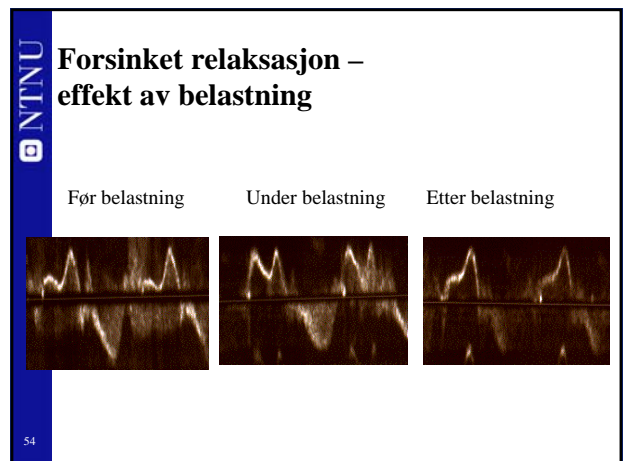
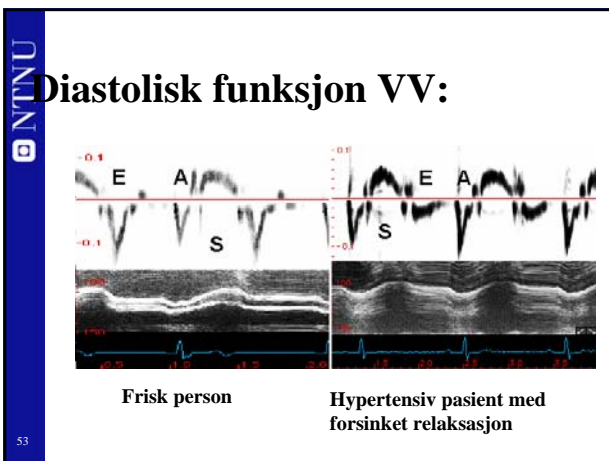
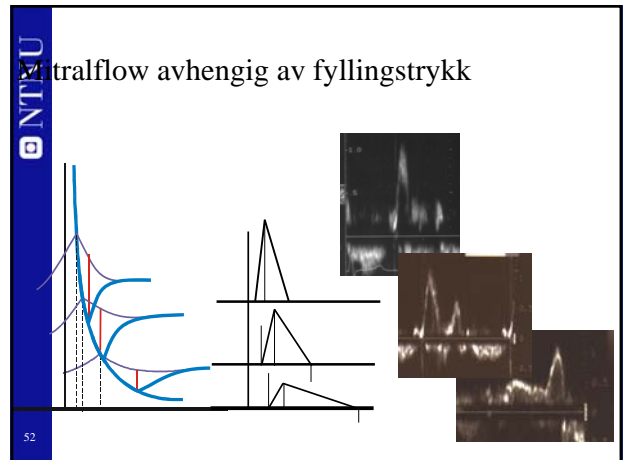
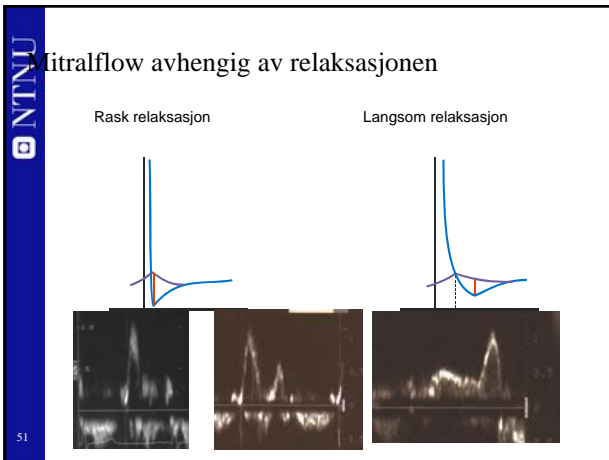
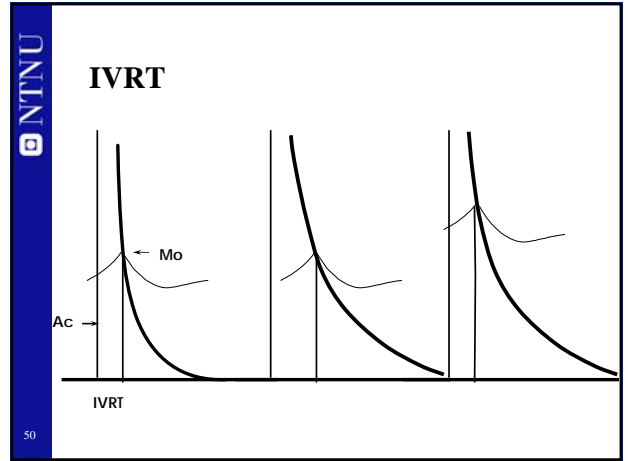
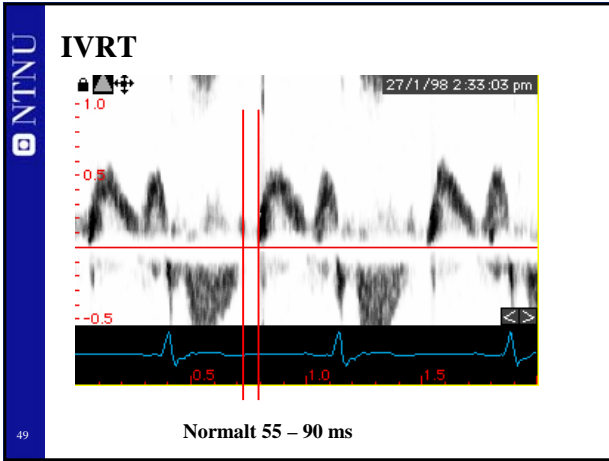
- Relaksasjon er rask til å begynne med
- Relaksasjonen er langsommere mot slutten

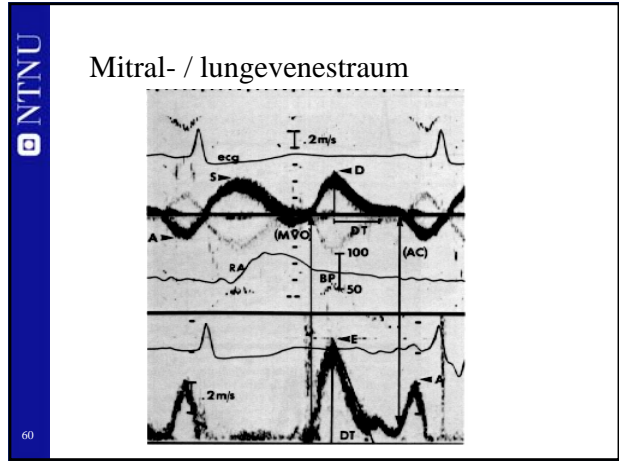
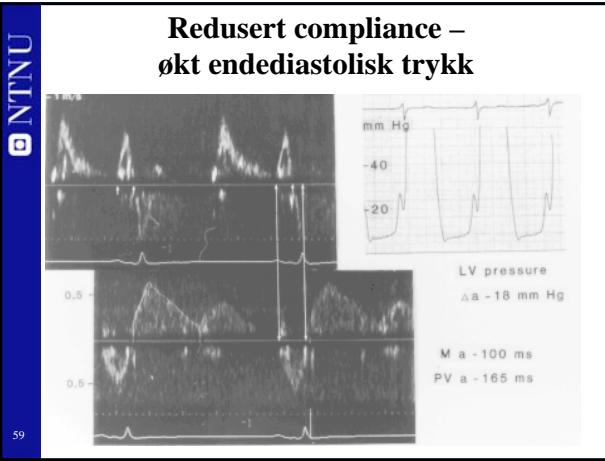
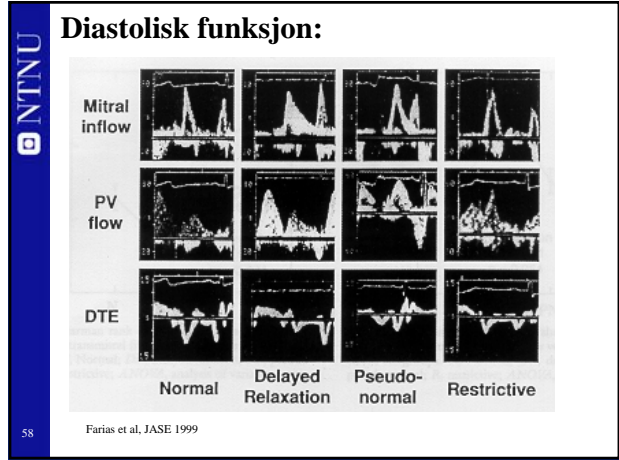
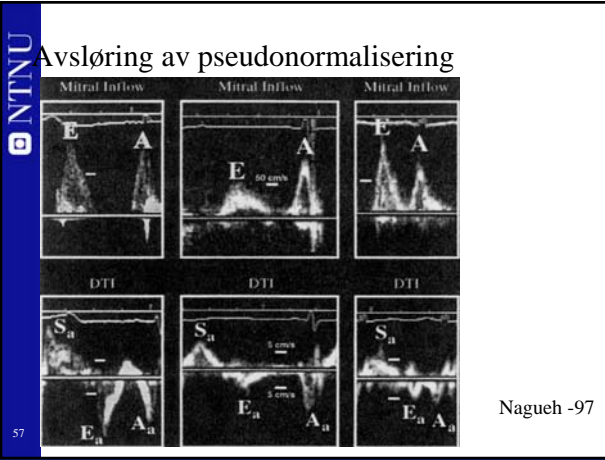
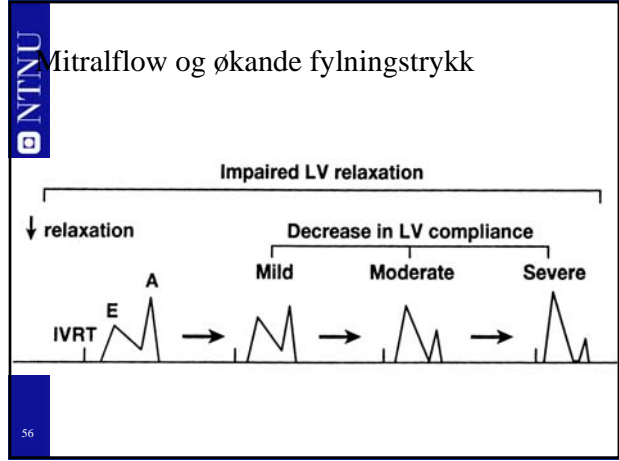
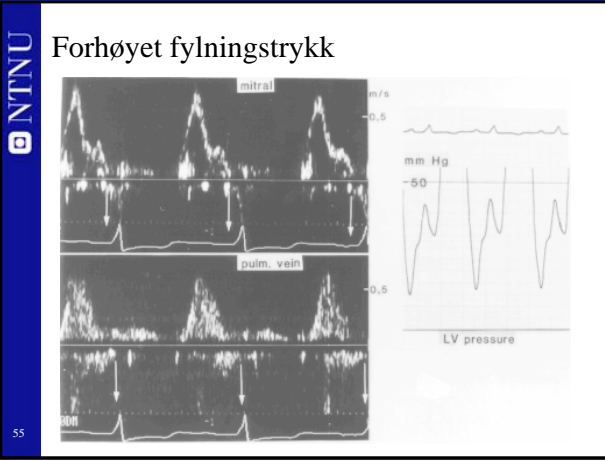


IVRT

IVRT

Tau: Tidskonstanten for trykkfallet under IVRT





Minuttvolumreserve

- Mål for maksimal pumpekapasitet.
- Kan ikke måles i hvile
- Ekko under maksimal anstrengelse lite praktisk, ekko under moderat anstrengelse kan gi indikasjoner

Oksygenopptak (VO_2):

- **Lungene: Luft → Blod**
 - Ingen begrensning hos lungefriske
- **Sirkulasjonen: Blod → vev**
 - Begrensning i transportkapasiteten (hjertet)
 - $VO_2 = \text{Minuttvolum} \times \text{A-V } O_2 \text{ differanse}$
- **Vevet: Perifert forbruk (→ mitochondrier)**
 - Begrensning bare hos inaktive

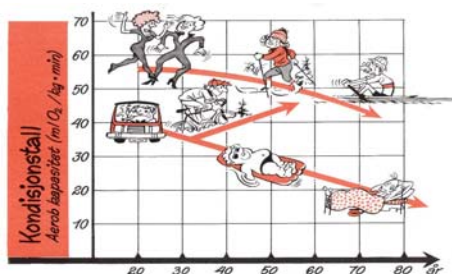
Kondisjon:

- = maksimalt oksygenopptak (VO_{2max}) måles i ml/kg/min
- $VO_{2max} = \text{Minuttvolum}_{max} \times \text{A-V } O_2 \text{ differanse}$
- Måles under maksimal aerob anstrengelse
- Kondisjonen (VO_{2max}) er altså et mål på hjertets pumpekapasitet

Maksimalt oksygenopptak (ml/kg/min):

- | | Kvinner | menn |
|--------------------|---------|-------|
| • Utrente 20 år: | 40 | 52 |
| • Utrente 45 år: | 31 | 40 |
| • Utrente 65 år: | 25 | 33 |
| • Vektløftere: | | 55 |
| • Fotballspillere: | | 55-65 |
| • Elite skiløpere: | 70 | 85 |
- (Hjertetransplantasjonskandidater: < 14)

Kondisjonen avtar med alderen:

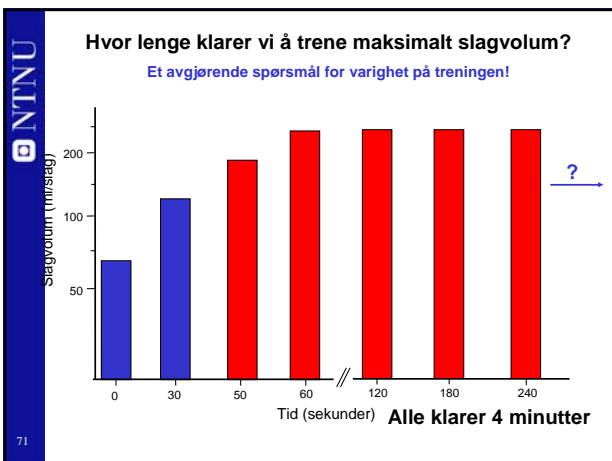
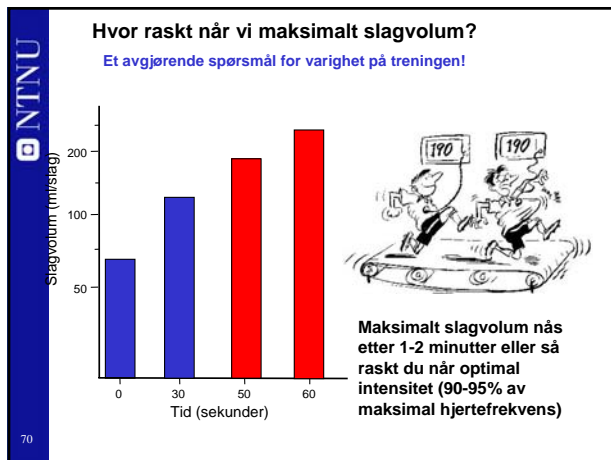
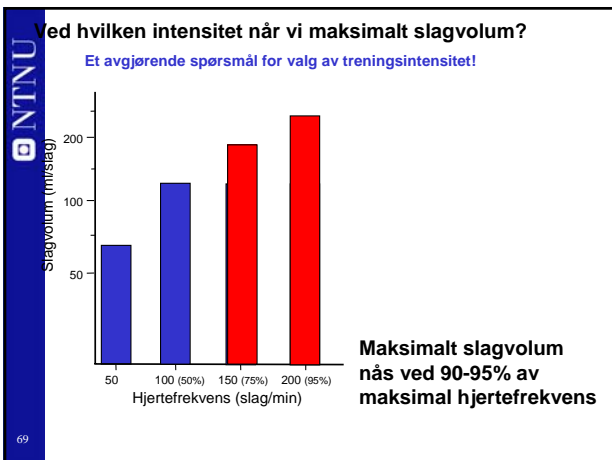
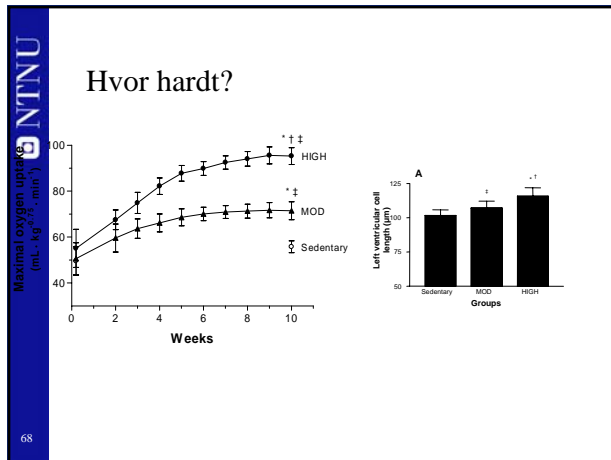
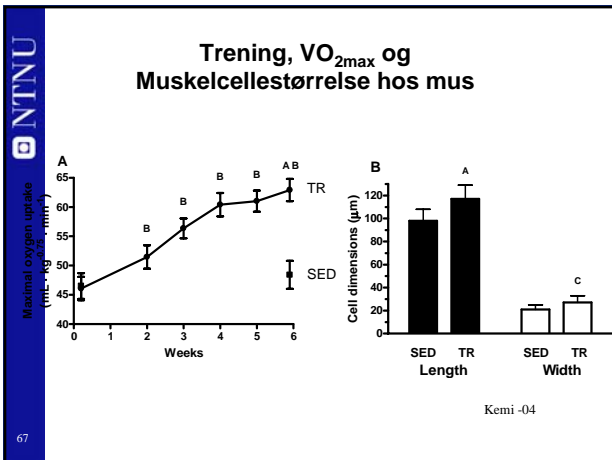


Hjertets pumpekapasitet begrenser maksimalt oksygenopptak!

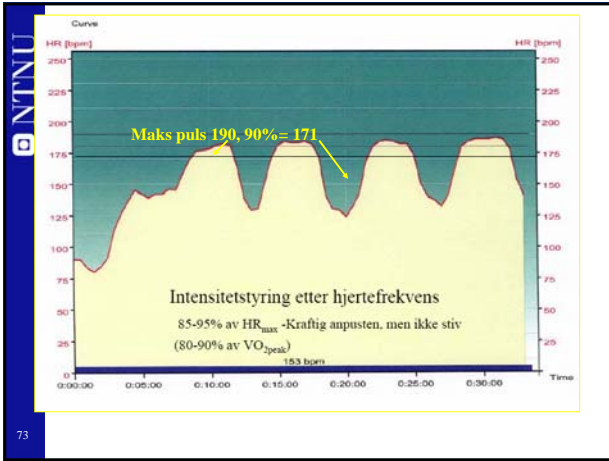
$$\begin{aligned} &\text{Hjertets pumpekapasitet} \\ &= \\ &\text{Hvor mye hjertet pumper per slag (slagvolum)} \\ &\times \\ &\text{Maksimal hjertefrekvens} \end{aligned}$$

Det eneste vi kan trene for å øke hjertets pumpekapasitet er slagvolum!

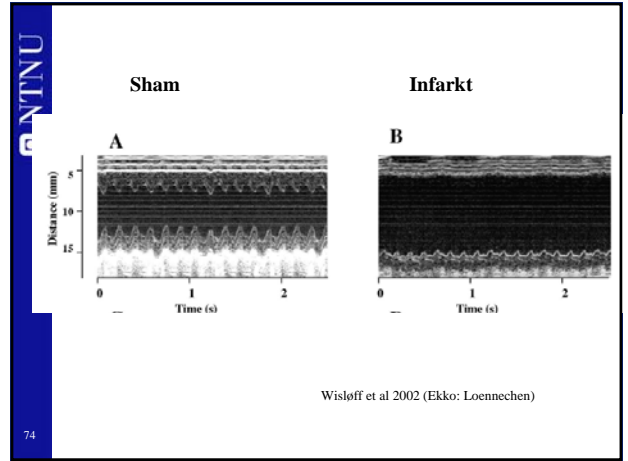




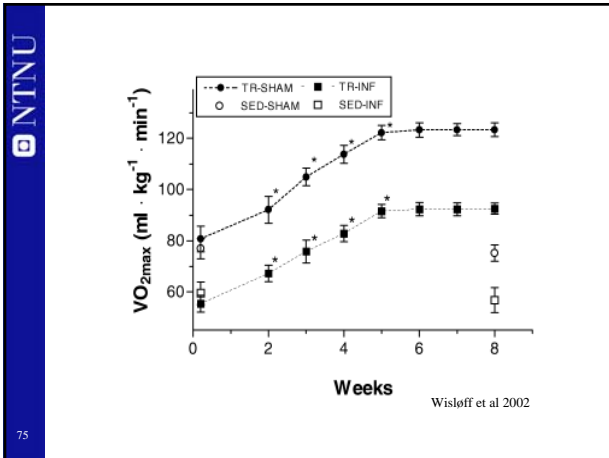
- ### Hvordan trene?
- 5 – 10 min oppvarming
 - 4 min ved 90% av maks puls
 - Så andpusten at en ikke kan snakke, men ikke stivne
 - 3 min aktiv pause (70% av maks puls)
 - 4 drag
 - 3 min rolig nedtrapping.
 - Løping, stavgang, skigåing, sykling, svømming, aerobics



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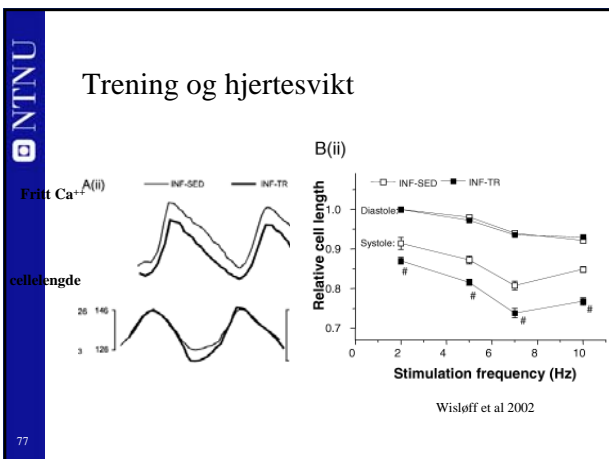
75

	SED-SHAM	TR-SHAM
Right ventricular mass (mg)	318.8 ± 29.2	405.1 ± 45.3**
Left ventricular mass (mg)	876.4 ± 74.1	1097.6 ± 84.5**
Left ventricular cell length (μm)	119.3 ± 1.8	134.3 ± 1.8**
Left ventricular cell width (μm)	25.50 ± 1.0	25.43 ± 1.1
Left ventricular infarction (%)	-	-

	SED-INF	TR-INF
Right ventricular mass (mg)	717.3 ± 76.6	555.2 ± 68.6**
Left ventricular mass (mg)	1575.1 ± 67.0	1339.0 ± 90.1**
Left ventricular cell length (μm)	156.0 ± 1.5	138.7 ± 1.2**
Left ventricular cell width (μm)	35.96 ± 1.1	28.63 ± 1.6**
Left ventricular infarction (%)	43.8 ± 2.2	44.9 ± 2.7

Wisløff et al 2002

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