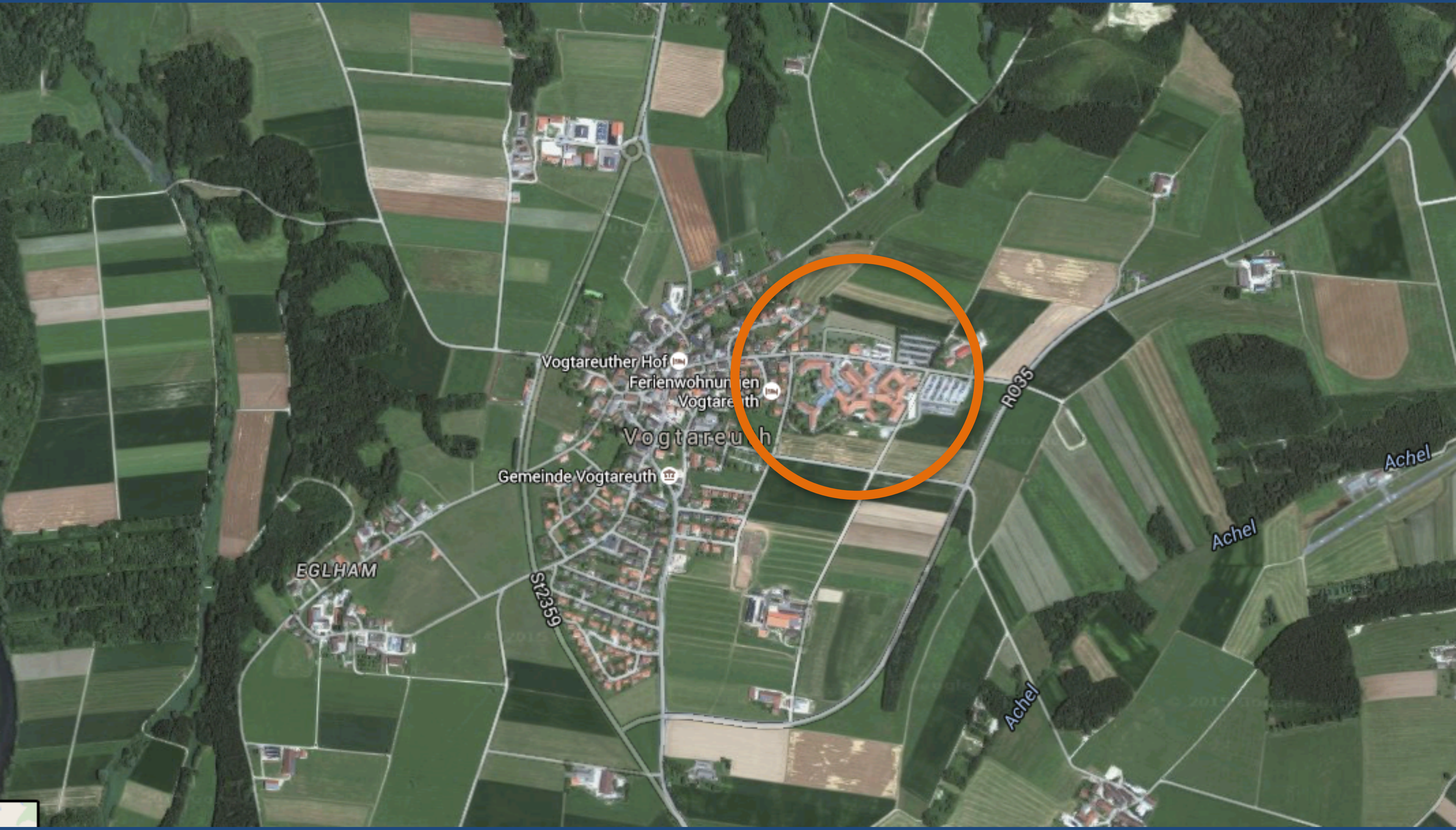
Carole Hamilton
Chief Perfusionist
Schön Klinik Vogtareuth, Germany


Schleswig-
Holstein
Mecklenburg-
Vorpommern
Hamburg
Bremen
Niedersachsen
Berlin
Brandenburg
Sachsen-
Anhalt
Nordrhein-
Westfalen
Sachsen
Thüringen
Hessen
Rheinland-
Pfalz
arland
Baden-
Württemberg
Bad Neustadt / Saale
Bayreuth
Würzburg
Erlangen-Nürnberg
Nürnberg
Regensburg
Passau
Augsburg
München
Vogtareuth

Schön Klinik Vogtareuth, Germany




E7
E2

Predictive Oxygenation

Keeping tight control over your paO_2s

What is....... Predictive Oxygenation

Being able to PREDICT the FiO_2

to achieve a NARROW TARGETED RANGE of paO_2

for each INDIVIDUAL PATIENT

What is....... Predictive Oxygenation

Being able to PREDICT the FiO_2

Oxygenator Performance using the $cFiO_2$

to achieve a NARROW TARGETED RANGE of paO_2

Optimal range of paO_2

for each INDIVIDUAL PATIENT

DO_2 and VO_2

Optimal range of paO_2

How much is needed?

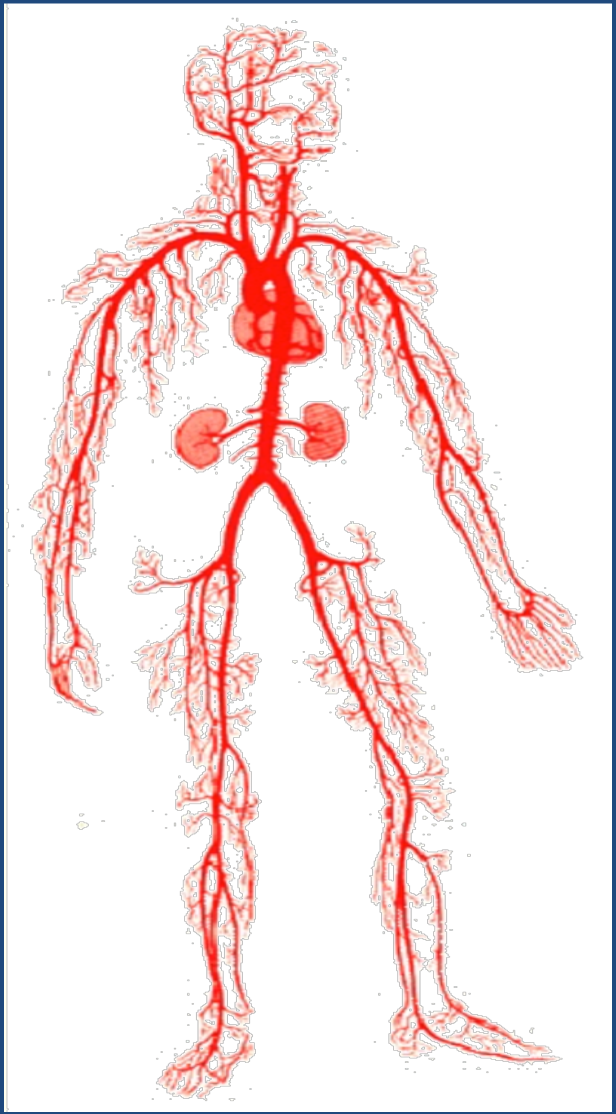
HYPEROXIA

There is no established definition
Author defined
$FiO_2 > 0.21$

The amount of research on oxygen free radicals and the detrimental effects noted on tissues is vast

HYPEROXIA during CPB
is probably harmful and should be avoided

HYPEROXIA…OXYGEN TOXICITY



Cerebral Vasoconstriction

-seizures

Pulmonary Vasodilatation

-edema

Peripheral Vasoconstriction

Alter microcirculatory response

Redistribute capillary blood flow

Reducing local tissue perfusion

Decreased muscle oxygenation

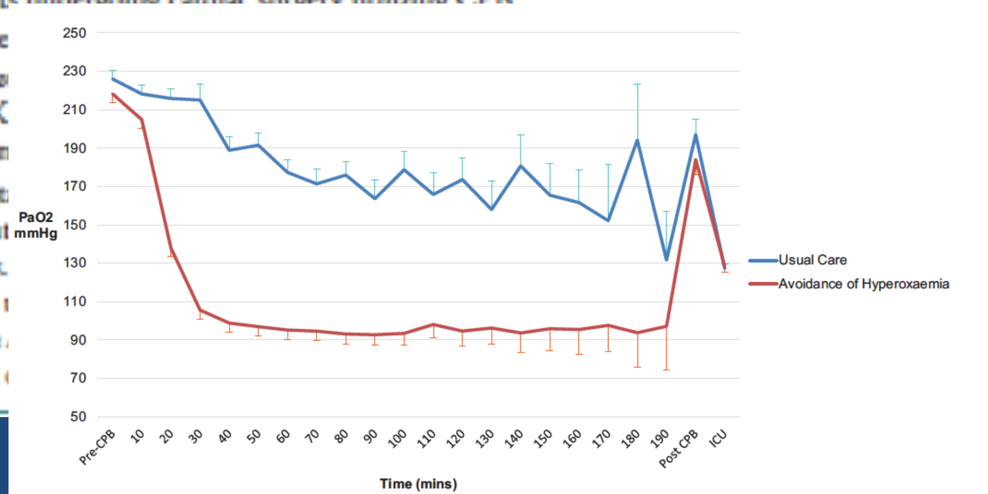
Willcox Paper (Anesthesiology 2016; 125:465-73)

A Multicenter, Randomized, Controlled Phase IIb Trial of Avoidance of Hyperoxemia during Cardiopulmonary Bypass

Shay P. McGuinness, M.B.Ch.B., Rachael L. Parke, Ph.D., Kate Drummond, M.B.B.S.,

In summary, the avoidance of modest hyperoxemia (mean, 178 mmHg) during CPB appears safe and achievable but failed to demonstrate any difference in AKI, markers of organ damage, or length of stay.

tion in patients undergoing cardiac surgery utilizing CPB.
Methods: The … f the avoidance of arterial
hyperoxemia … me was the incidence and
severity of AK… chanical ventilation, and
length of inten…
Results: A tot… and Australia. Mean Pao_2
was significant… ent of AKI (intervention
arm 72.0% vs. … rkers of organ damage, or
intensive care …
Conclusions: … KI, markers of organ dam-
age, or length …



Sooo..........................To prevent Hyperoxia

Important to be able to target a narrow range of paO_2s on CPB

Our Target is 150 mmHg

SvO_2>70%

DaO_2/m^2>272 $mlO_2/min/m^2$

$paCO_2$ between 38-42 mmHg

No Parameter stands alone

Smaller Systems
Less Hemodiltion
Higher Hemoglobin
Better Oxygen Delivary

Do we really need higher paO_2s?

Original Paper

Perfusion

Perfusion
1–8

DOI: 10.1177/0267659116668400
prf.sagepub.com
SAGE

A new method to measure oxygenator oxygen transfer performance during cardiopulmonary bypass: clinical testing using the Medtronic Fusion oxygenator

Carole Hamilton,[1,2] Denise Marin,[1] Frank Weinbrenner,[1] Branka Engelhardt,[1] Dow Rosenzweig,[1] Ulrich Beck,[1] Pavel Borisov[1] and Stephen Hohe[1]

Abstract

Background: There is no acceptable method of testing oxygen transfer performance in membrane oxygenators quickly and easily during cardiopulmonary bypass. Pre-clinical testing of oxygenators is performed under controlled situations in the laboratory, correlating oxygen transfer to blood flow using 100% oxygen. This laboratory method cannot be used clinically as oxygen transfer values vary significantly at each blood flow and the FiO_2 is not kept at 1. Therefore, a formula was developed which corrects the existing FiO_2 to attain a PaO_2 of 150 mmHg: the corrected FiO_2 at 150 mmHg. In graph form, this corrected FiO_2 (x-axis) is correlated to the patient's oxygen consumption levels (y-axis), which determines the membrane oxygenator oxygen transfer performance.

Methods: Blood gas and hemodynamic parameters taken during cardiopulmonary bypass using the Medtronic Fusion were used to calculate the oxygen consumption (inlet conditions to the oxygenator) and the corrected FiO_2 for a PaO_2 of 150 mmHg. Validation of the formula "FiO_2-PaO_2/(Pb-pH_2O)+0.21" was carried out by plotting the calculated values on a graph using PaO_2 values between 145 to 155 mmHg and then, using the corrected FiO_2 for PaO_2s outside of this range.

Results: All trend-lines correlated significantly to confirm that the Medtronic Fusion had an extrapolated oxygen transfer of 419 milliliters O_2/min at an FiO_2 of 1 to achieve a PaO_2 of 150 mmHg.

Conclusions: Use of the corrected FiO_2 correlated to the oxygen transfer conditions of the membrane oxygenator can easily be used on a routine basis, providing valuable information clinically. When used by the manufacturer under laboratory conditions, further clinically relevant data is provided in terms of FiO_2 and resultant PaO_2s instead of the present limitations using blood flow. In this way, a clinically justifiable method has been developed to finally establish a standard in testing membrane oxygenator performance.

Keywords

cardiopulmonary bypass; oxygen transfer; oxygen consumption; membrane oxygenator; FiO_2; PaO_2

Oxygenator Performance using the $cFiO_2$

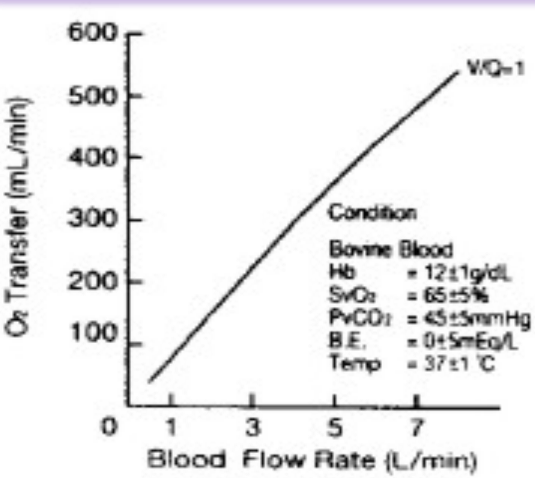
As far back as 1972, Galletti wrote, "There is no universally accepted way of measuring gas transfer capacity of artificial lungs."[1] Describing oxygenator gas exchange from clinical data remains difficult because there is no well-accepted technique and it is difficult to compare clinical and laboratory data.[2] These statements hold true today in that the pre-clinical phase of testing membrane oxygenators may provide some information for clinical use, but it cannot be adapted as a method to be used during cardiopulmonary bypass (CPB).

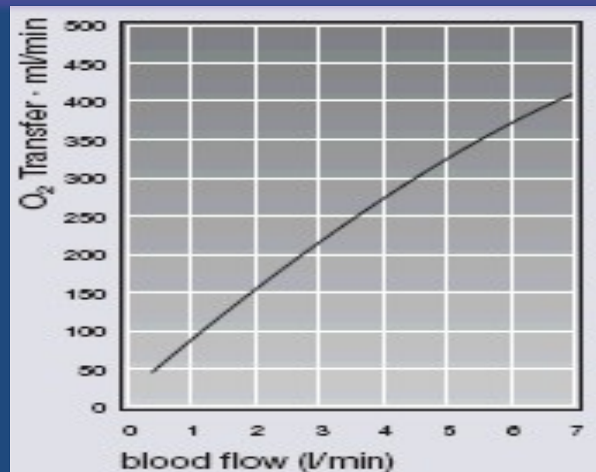
Before release to market, manufacturers use the guidelines set by the Association for Advancement of

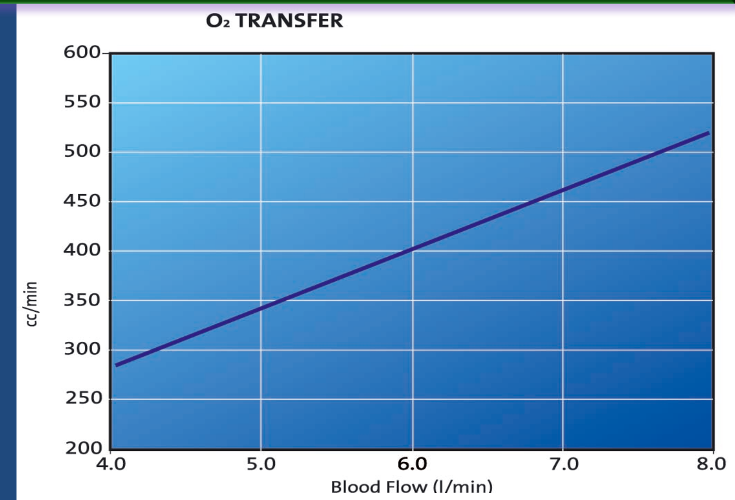
[1]Cardiac Surgery, Schoen Klinik Vogtareuth, Vogtareuth, Germany
[2]Life Systems, Monchengladbach, Germany

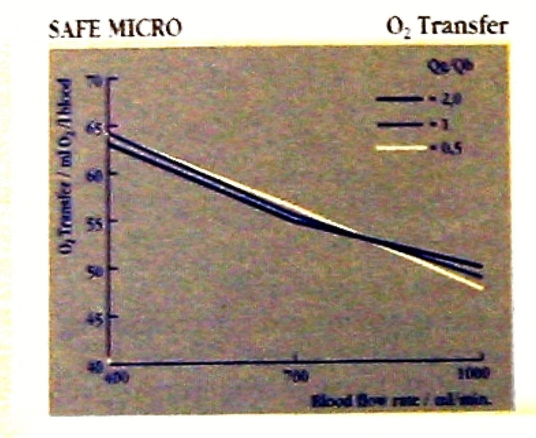
Corresponding author:
Carole Hamilton, Schoen Klinik Vogtareuth, Krankenhausstr 20, Vogtareuth, 83569, Germany.
Email: Carole.hamilton@gmx.net

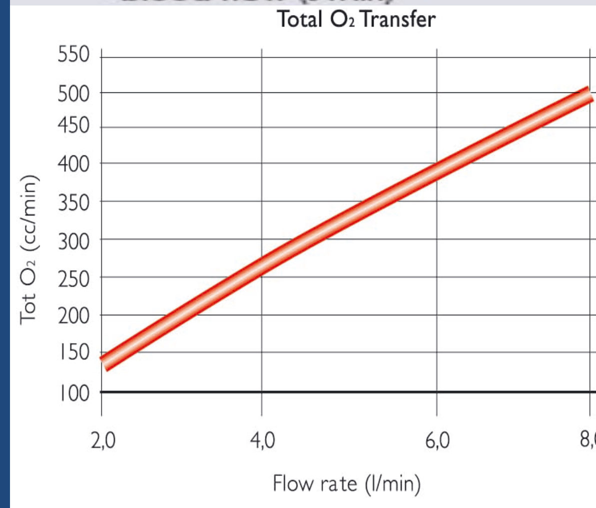
Oxygenator Performance

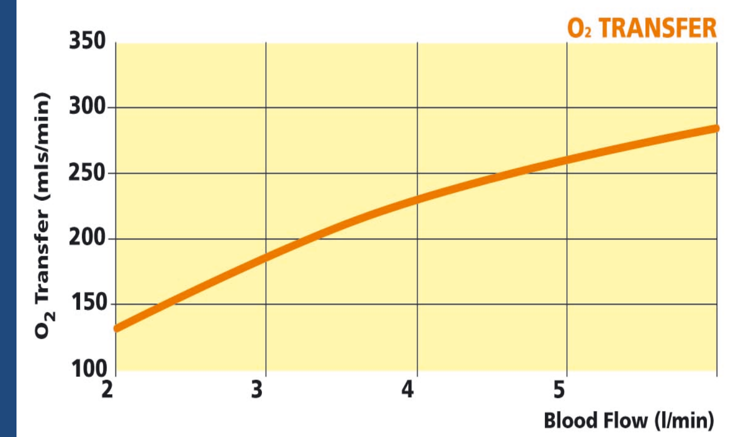








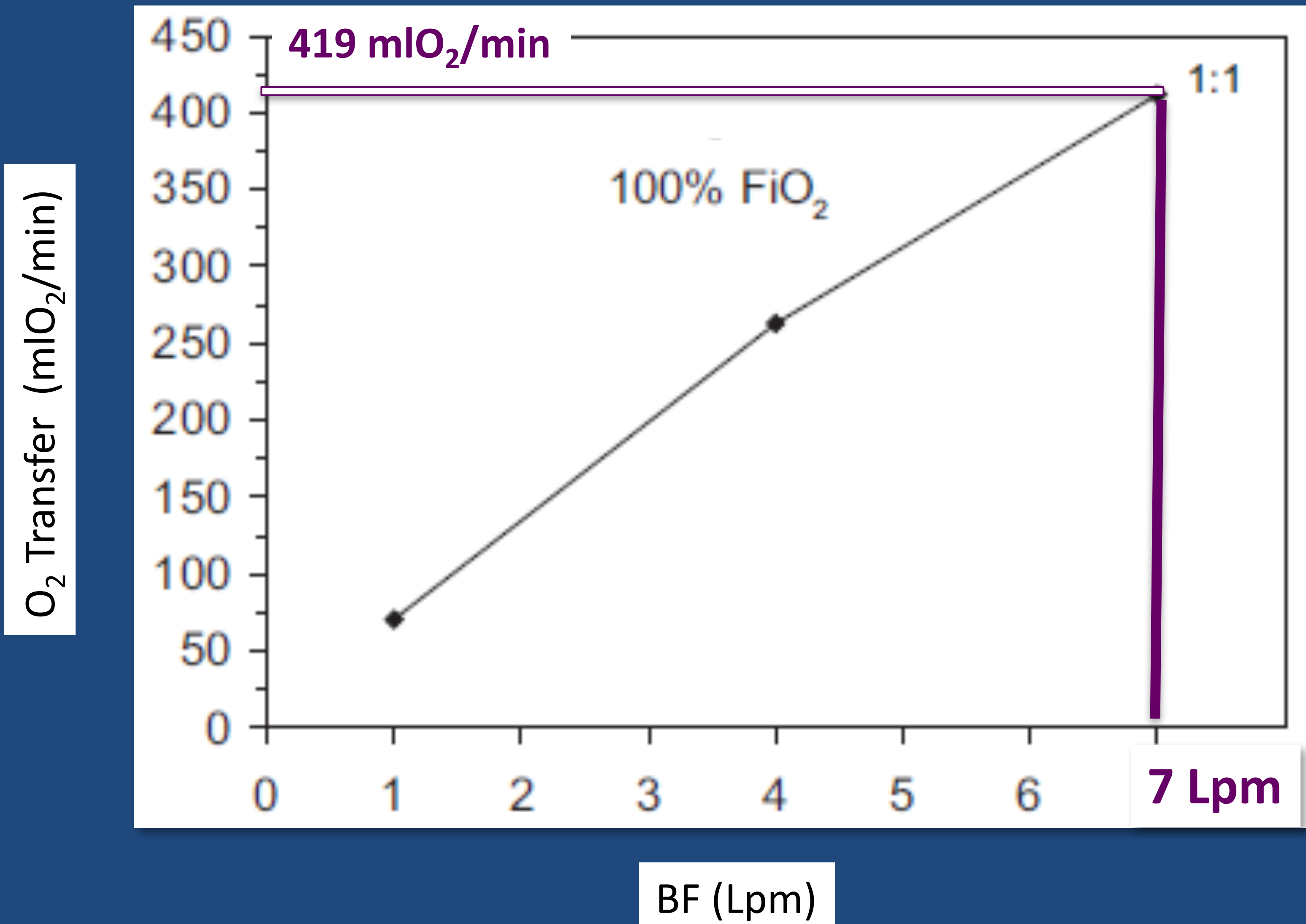




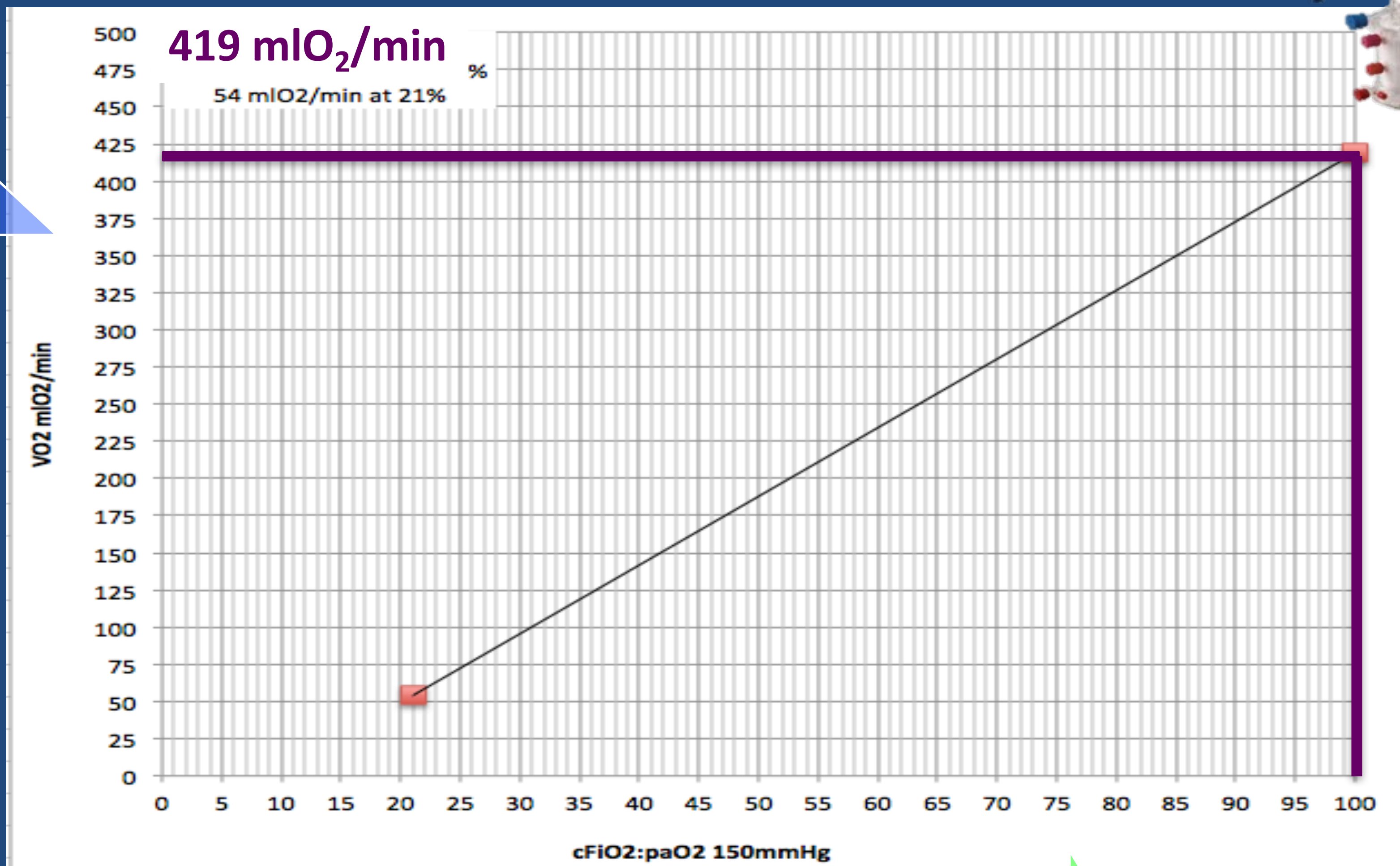
Gitterlines, Units, O_2 Transfer lines (thickness, shape), Scales

There are no guidelines

Medtronic O_2T Graph



Medtronic O_2T Graph using the $cFiO_2$



Hemoglobin
SvO_2
Blood flow

$cFiO_2$:150 mmHg

Corrected FiO_2

$cFiO_2$:150 mmHg

Barometric Pressure 760 mmHg

Water Vapour Pressure 47 mmHg

150 mmHg/(760-47)mmHg=0.21 FiO_2

Inspired air has 0.21 FiO_2

„Express any PaO_2 as a Fraction (FaO_2)“

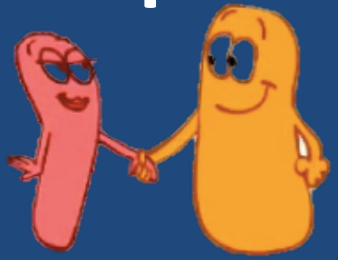
Corrected FiO_2

$cFiO_2$:150 mmHg

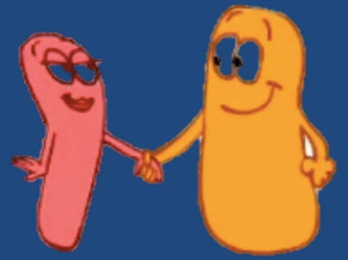
„Take any PaO_2
and convert to a Fraction (FaO_2)“

„Compare to FiO_2 used during CPB“

Gives you the paO_2....FiO_2 relationship



Corrected FiO_2 ($cFiO_2$:150 mmHg)



paO_2....FiO_2 relationship

$$200/(760-47)=0.28\ FiO_2$$

0.28 | 0.22

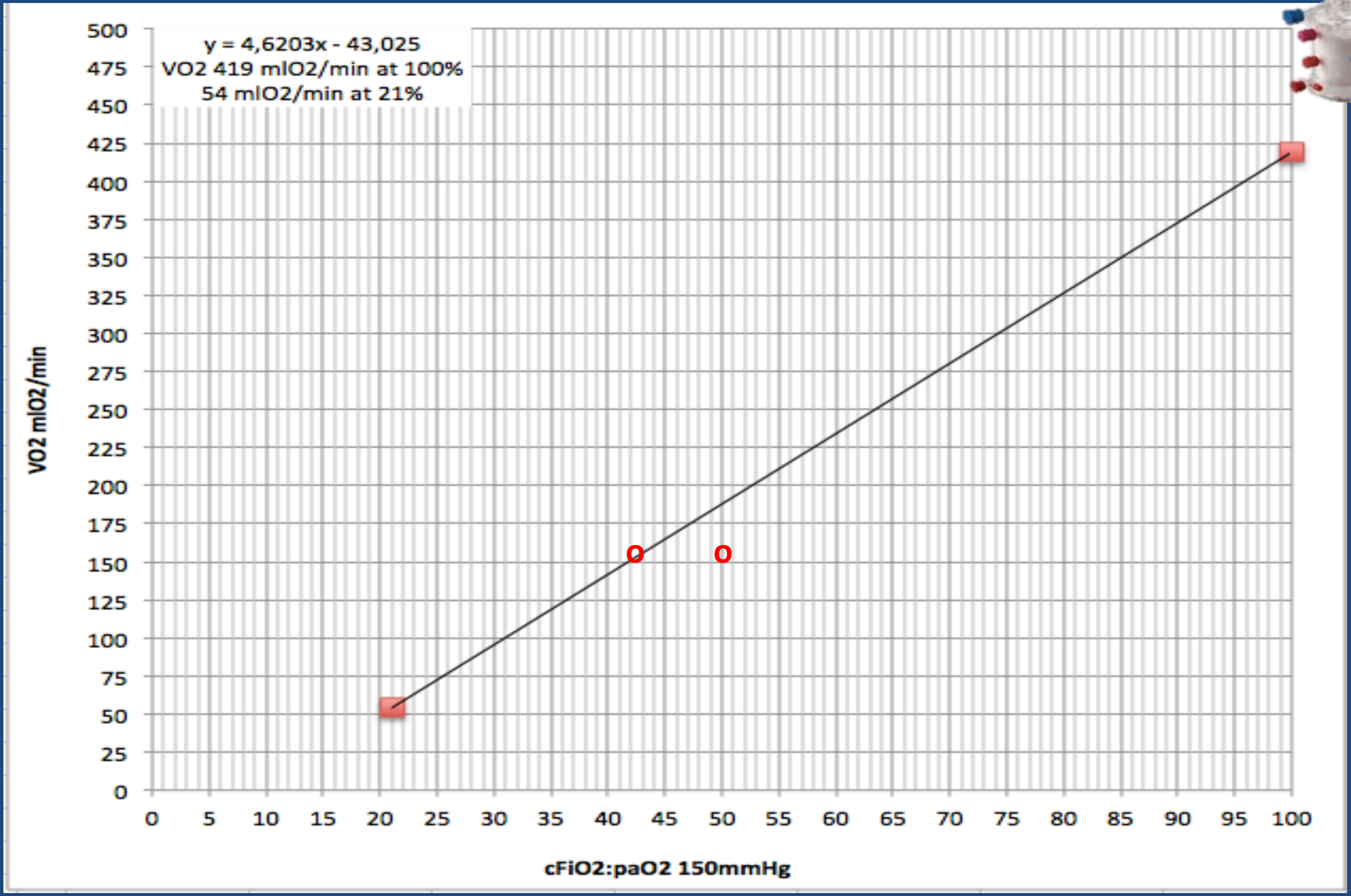
0.50

$$150/(713)=0.21\ FiO_2$$

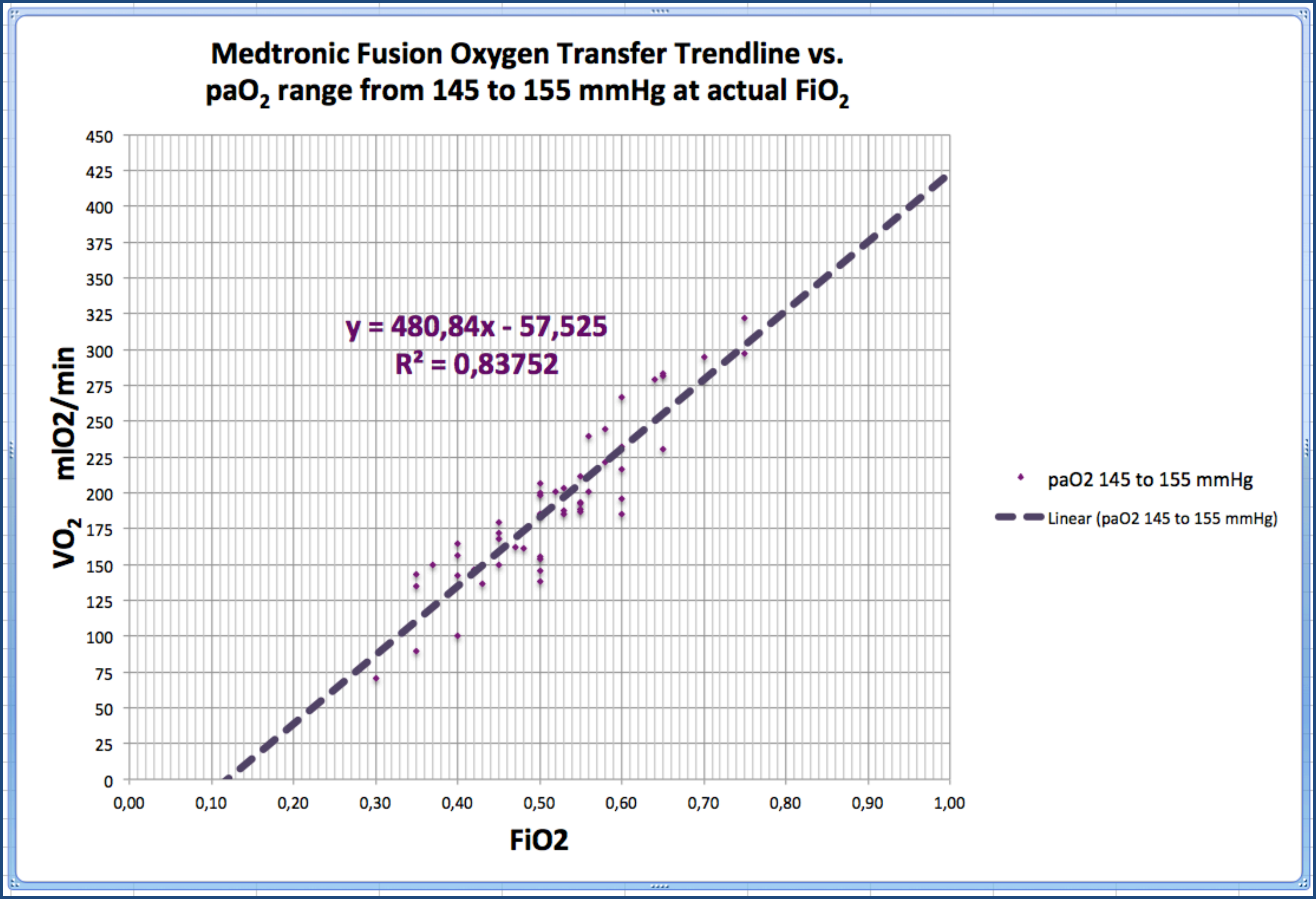
0.21 | 0.22

0.43 $cFiO_2$:150 mmHg

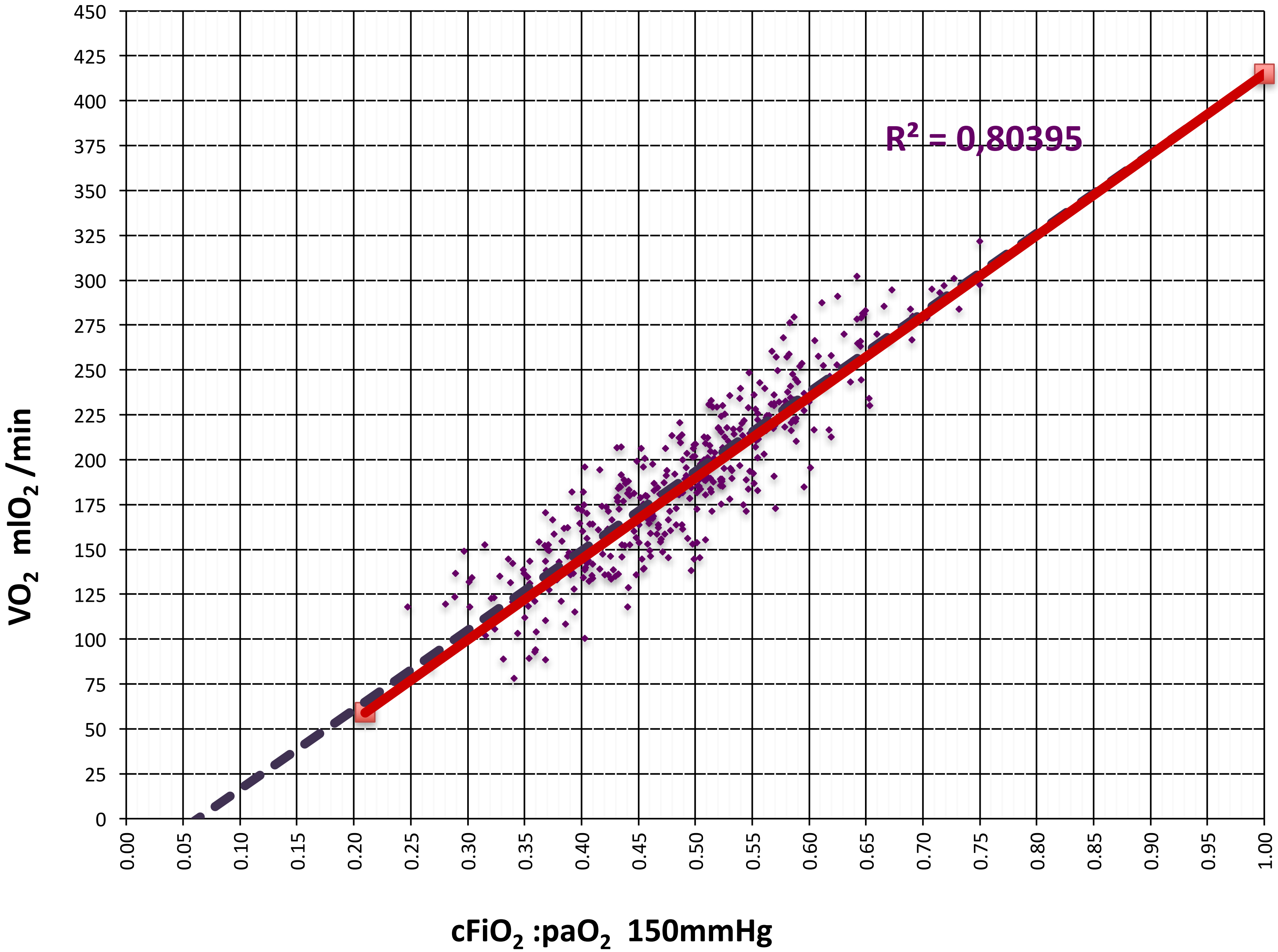
Medtronic O_2T Graph using the $cFiO_2$



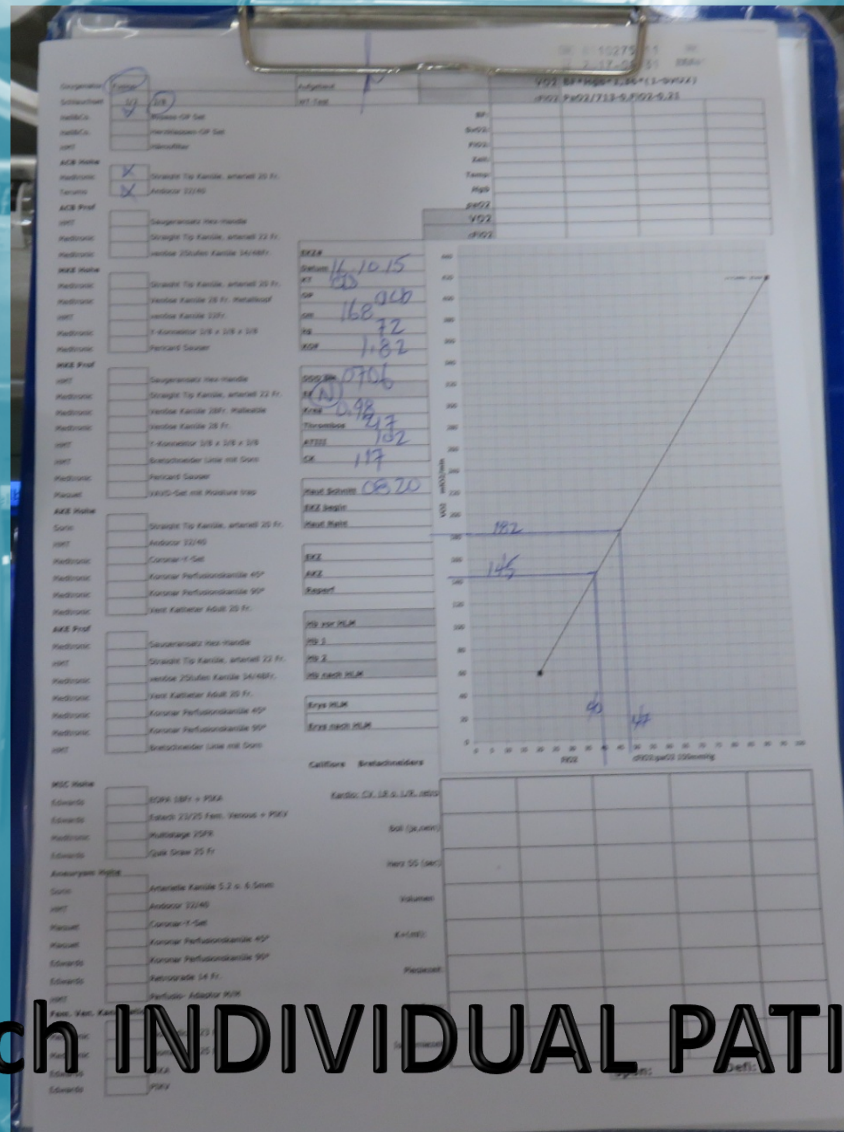
Clinical paO_2s Ranging from 145 to 155 mmHg
Using blood gases taken between 34 to 37 degrees



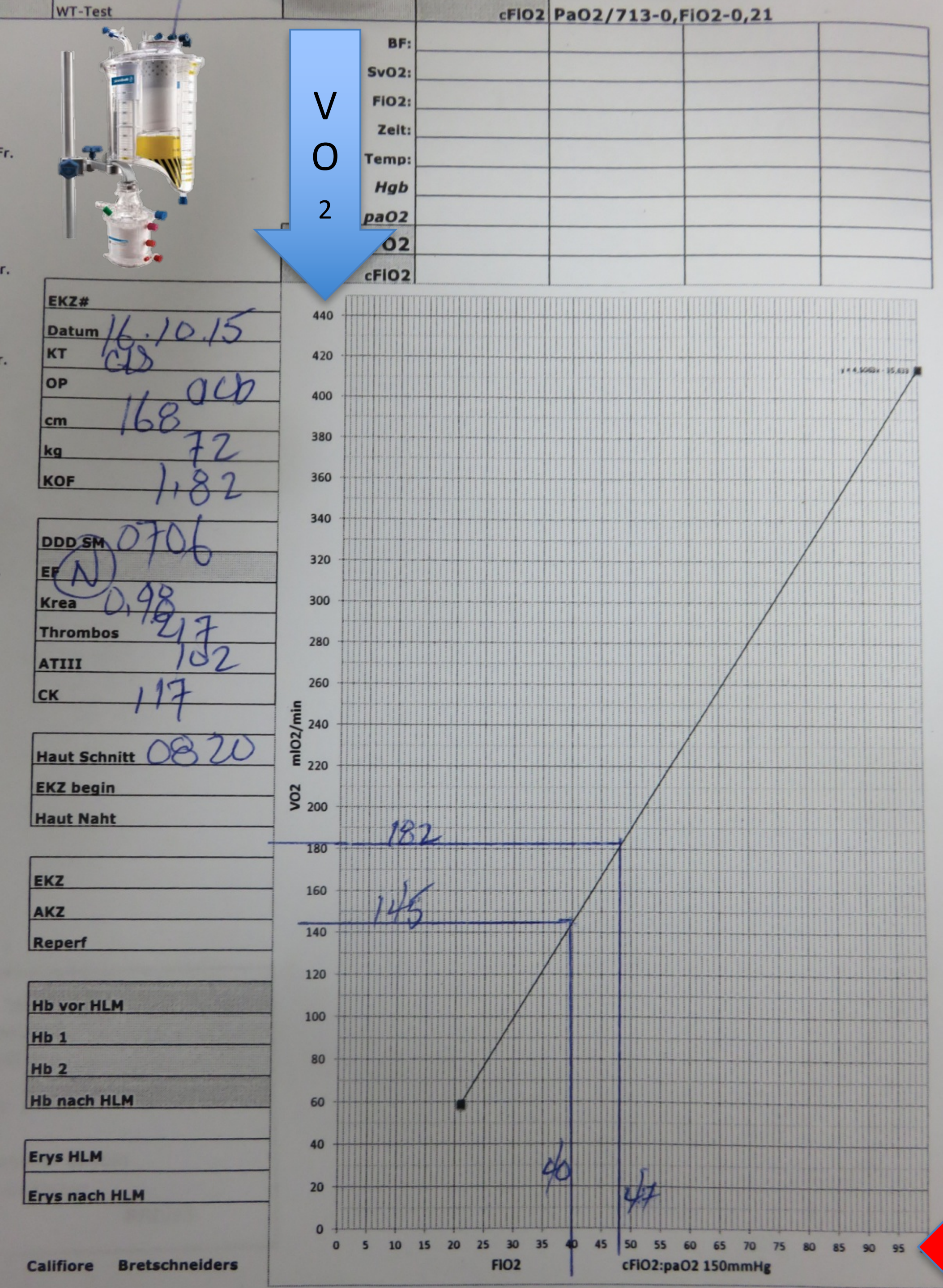
VO_2 vs. $cFiO_2$: 150 mmHg



DO_2 and VO_2



for each INDIVIDUAL PATIENT



Before CPB

Theoretical VO_2

$100\ mlO_2/min/m^2$

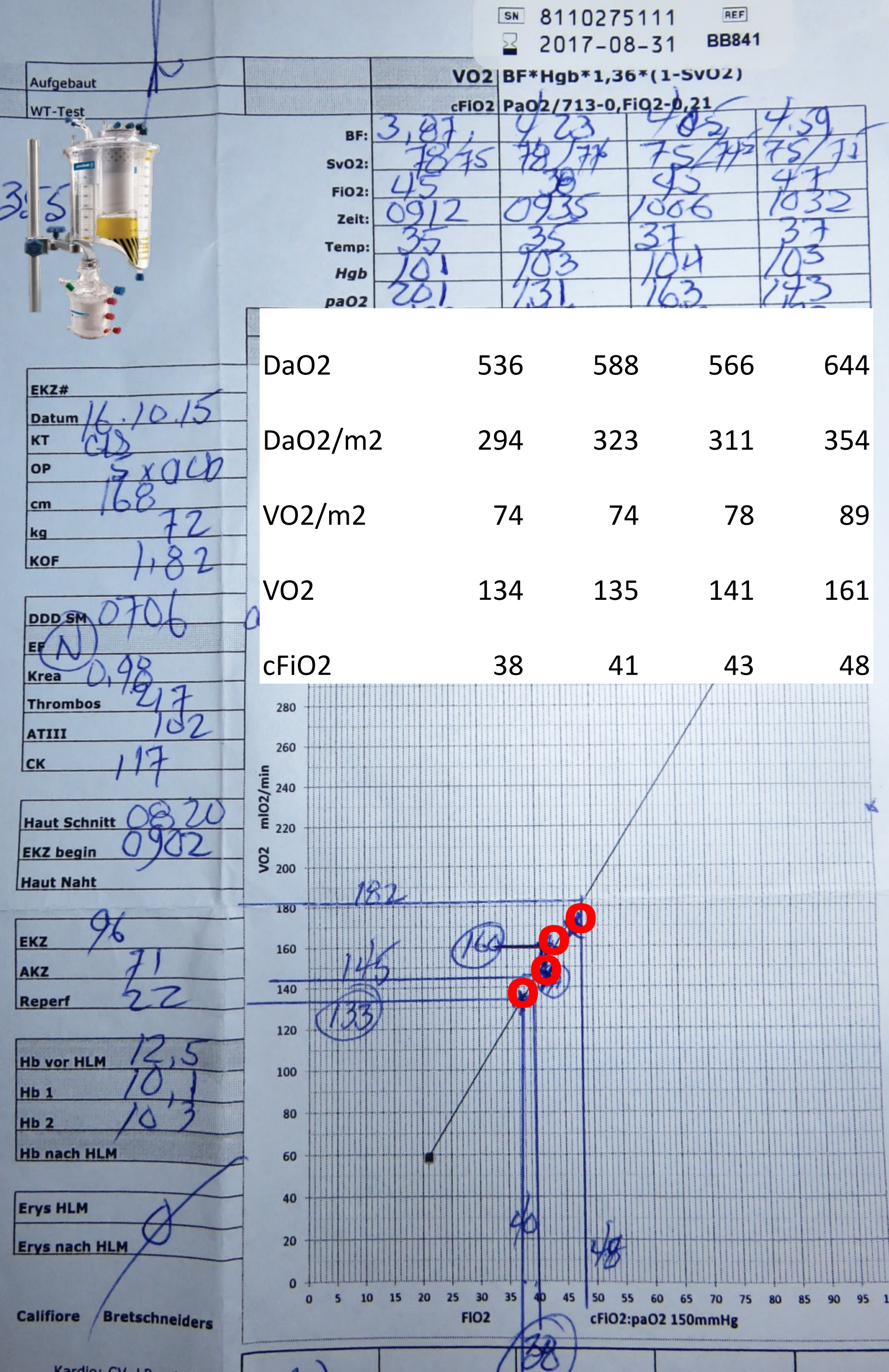
$80\ mlO_2/min/m^2$

Patient: 168 cm/ 72 kg

BSA 1.82 m^2

$182\ mlO_2/min/m^2$	FiO_2 47
$145\ mlO_2/min/m^2$	FiO_2 40

$cFiO_2$:150mmHg



DaO2	536	588	566	644
DaO2/m2	294	323	311	354
VO2/m2	74	74	78	89
VO2	134	135	141	161
cFiO2	38	41	43	48

BF 3.81

SvO_2 75

FiO_2 0.45

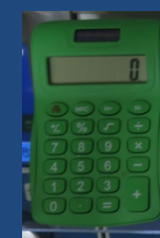
Temp 35

paO_2 201

Hgb **101**

paO_2 201/713=0.28-0.21=0.07

$cFiO_2$ 0.45-0.07=0.38



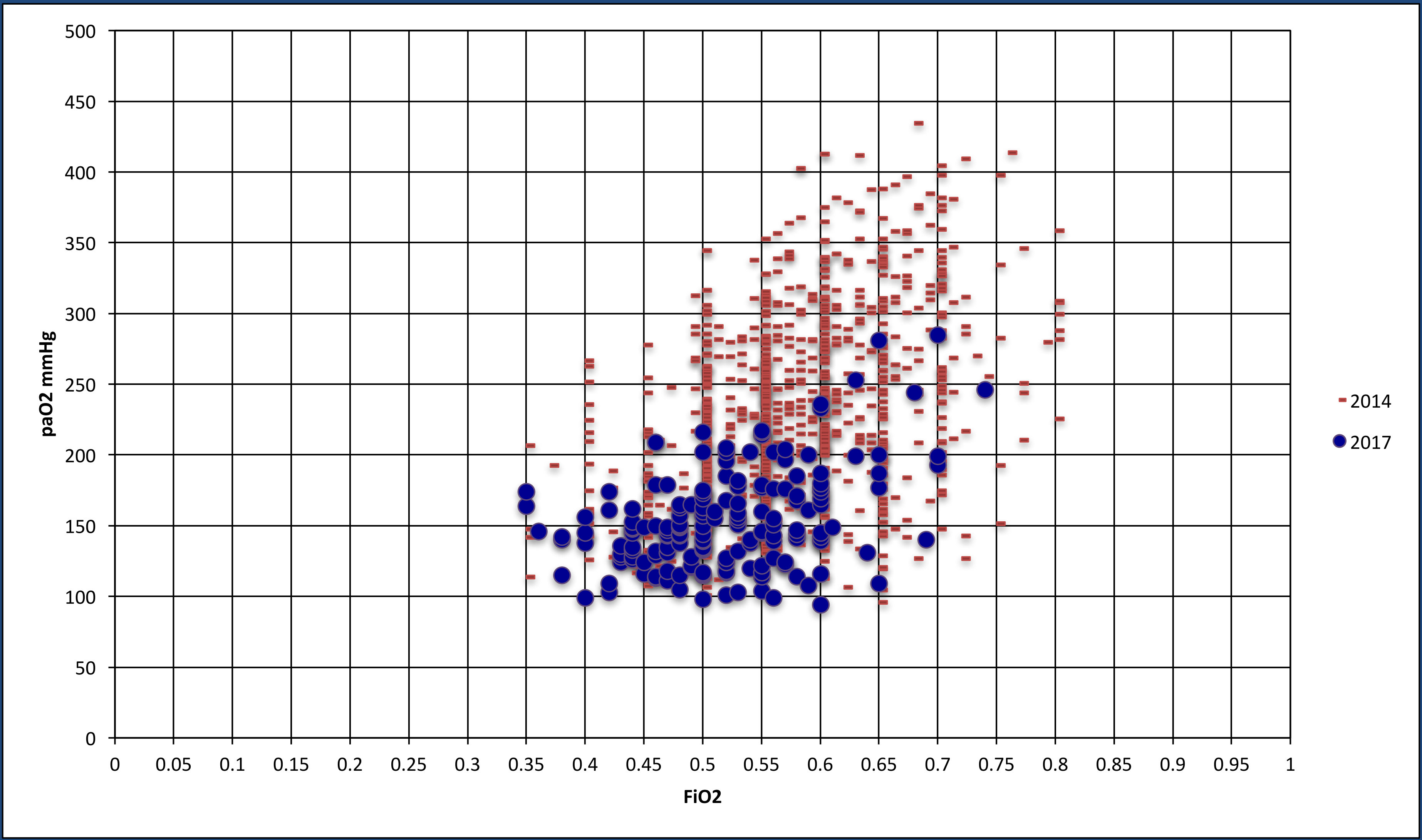
DaO_2 **101***1.36*3.81=532 mlO_2/min

DaO_2/m^2 532/1,82=292 $mlO_2/min/m^2$

VO_2/m^2 **292*(1-0.75)=73** $mlO_2/min/m^2$

VO_2 **73*1.82**=133 mlO_2/min

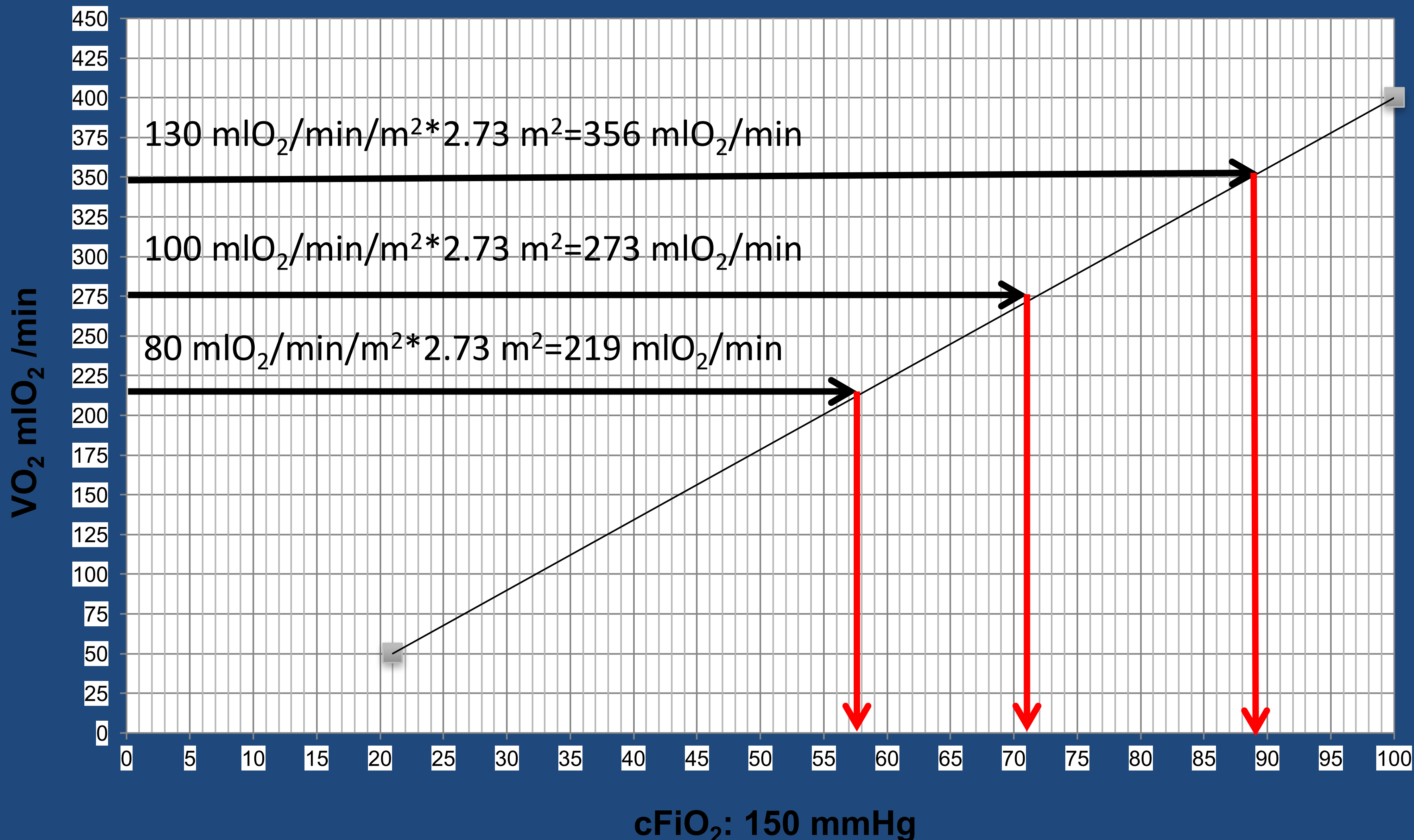
paO_2s from 2014 and 2017



Applications

$cFiO_2$:150mmHg

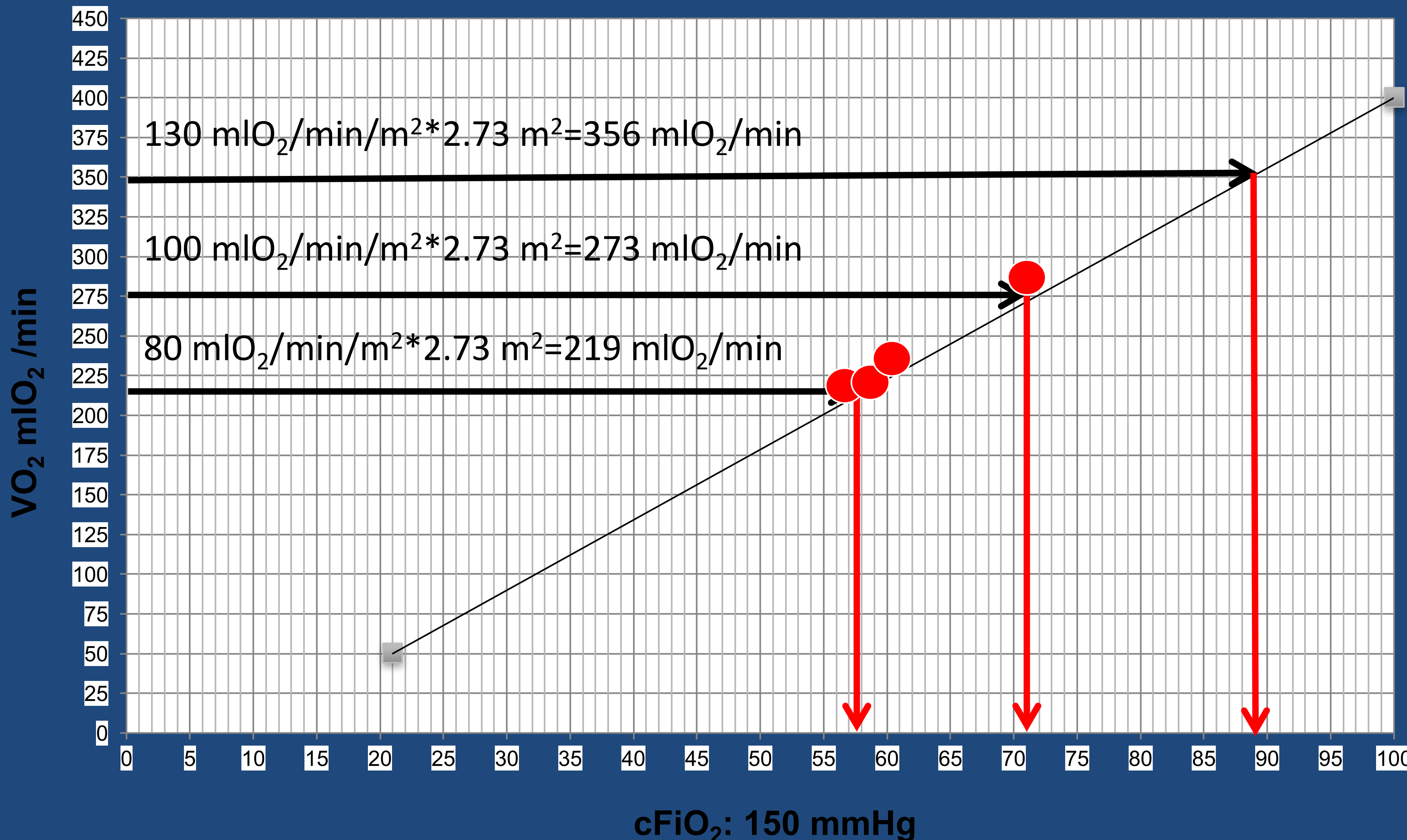
Mr. Big 48 year old male
179 cm, 170 kg, 2.73 m^2
Ascending Aneurysm, Aortic Valve Insufficiency



Mr. Big 48 year old male
179 cm, 170 kg, 2.73 m^2
Ascending Aneurysm, Aortic Valve Insufficiency

Hemoglobin (gms/dL)	11.9	12.1	12.3	12.5
SvO_2 %	73	76	72	67
Temperature (°C)	34	34	34	37
BF (Lpm)	5.0	5.3	4.9	5.6
CI (Lpm/m^2)	1.8	1.9	1.8	2.1
FiO_2	0.65	0.65	0.65	0.65
paO_2 (mmHg)	226	209	197	105
DaO_2 (mlO_2/min)	829	881	833	939
DaO_2/m_2 (mlO_2/min)/m^2	303	324	304	343
VO_2/m_2 (mlO_2/min)/m^2)	84	80	85	107
VO_2 (mlO_2/min)	229	219	233	295
cFiO2:150 mmHg	60	57	60	72

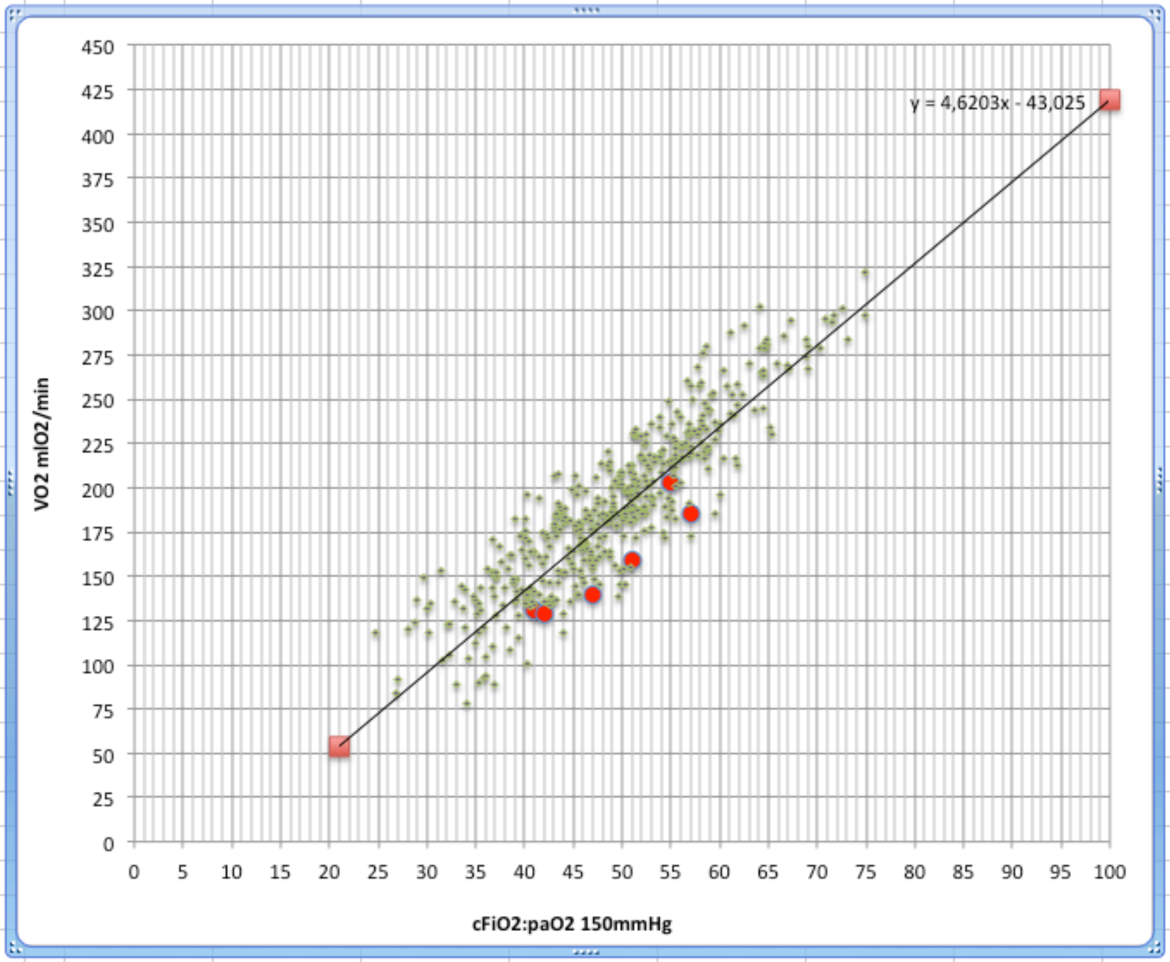
Mr. Big 48 year old male
179 cm, 170 kg, 2.73 m^2
Ascending Aneurysm, Aortic Valve Insufficiency



Compare other Oxygenators

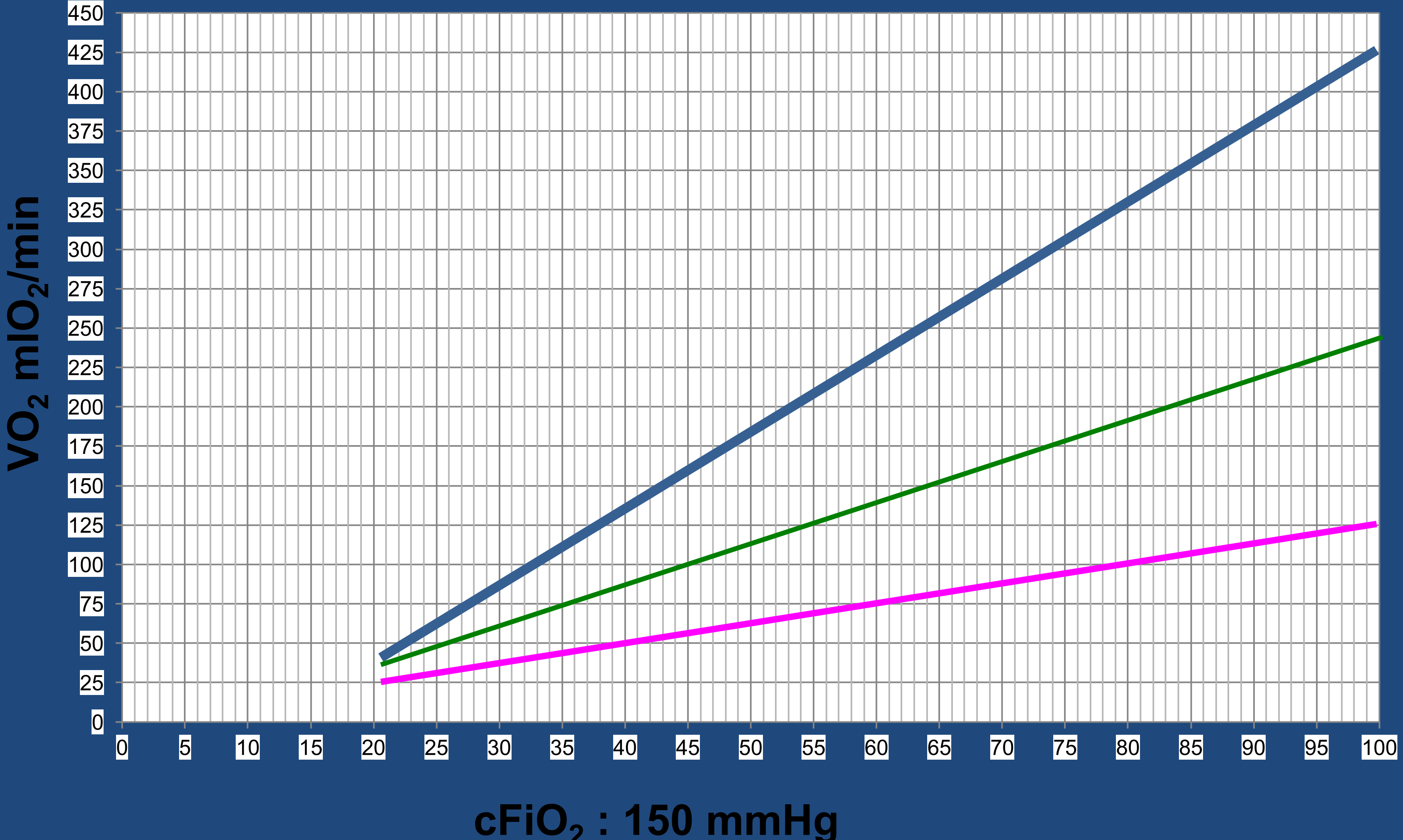
VO2	cFiO2
131	41
129	42
159	51
203	55
139	47
185	57

VO2	cFiO2
419	100
54	21



VO2	FiO2
78,3	34
84,2	27
88,4	37
88,9	33
89,5	35
91,9	27
93	36
93,99	36
100,4	40
102	32
103,3	34
104	36
105,7	32
108,5	39
110,3	37
112	35
115	39
118	44
118	25
118	30
118	35
120	28
121	34
121	38
121	36
123	32
123	32
124	29
[illegible]	[illegible]

Oxygen Transfer of other Oxygenators



We have the Technology

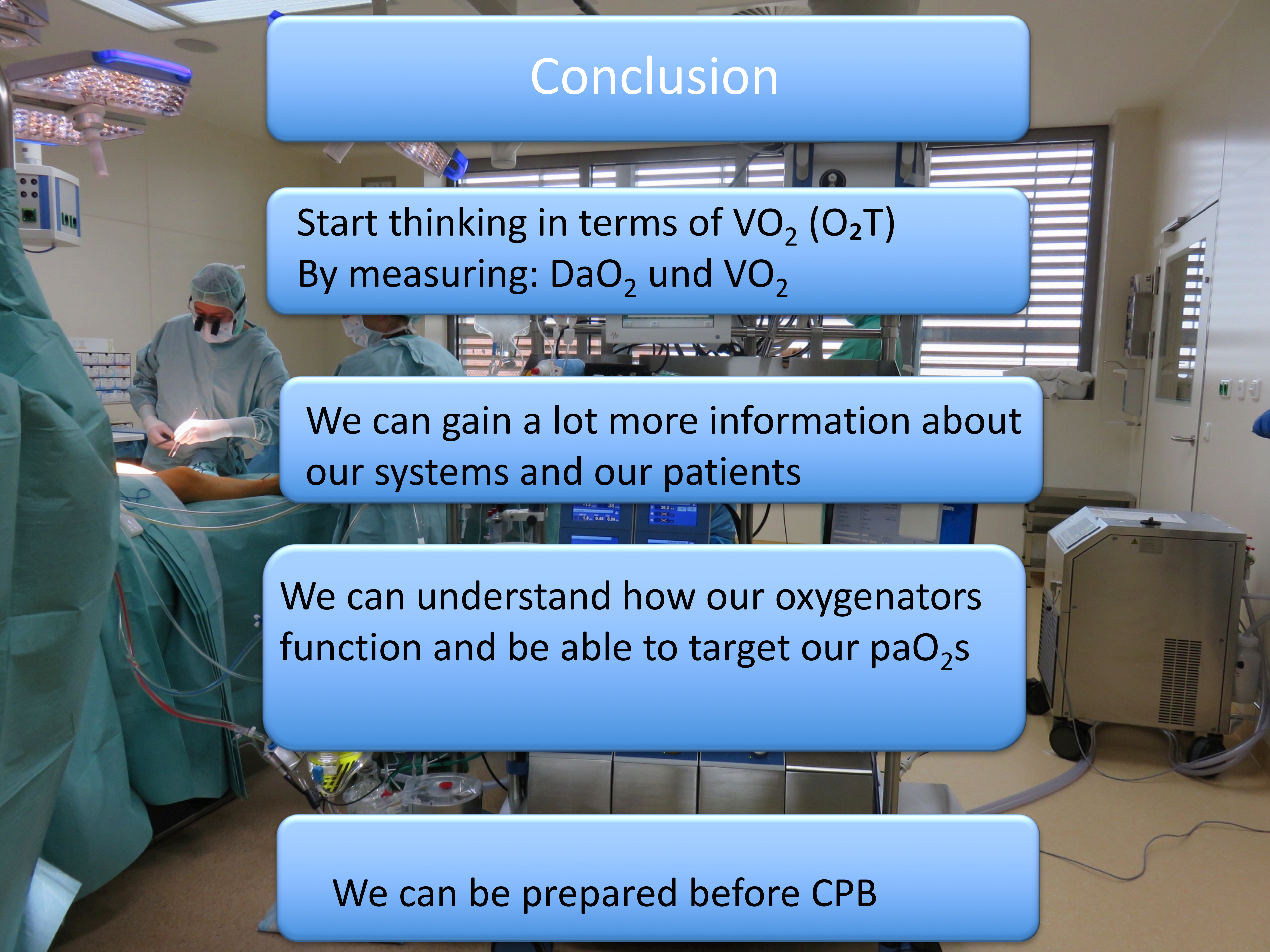
We have come a long way as far as technology in monitoring systems is concerned

Extracorporeal Circulation

Perfusion Flow Rate Based on Body Surface Area (BSA) (Clark, 1958.)

Blood Flow in (L/m²/min)

Body Surface Area (m²)	10 gm hemoglobin		12 gm hemoglobin		14 gm hemoglobin	
0.4	1.1	2,8	0.8	2,0	0.7	1,8
0.6	1.7	2,8	1.4	2,3	1.2	2,0
0.8	2.0	2,5	1.7	2,1	1.4	1,8
1.0	2.4	2,4	2.0	2,0	1.7	1,7
1.2	2.7	2,3	2.2	1,8	1.8	1,5
1.4	3.0	2,1	2.4	1,7	2.2	1,6
1.6	3.4	2,1	2.8	1,8	2.4	1,5
1.8	3.9	2,2	3.2	1,8	2.8	1,6
2.0	4.3	2,2	3.6	1,8	3.1	1,6



Conclusion

Start thinking in terms of VO_2 (O_2T)
By measuring: DaO_2 und VO_2

We can gain a lot more information about our systems and our patients

We can understand how our oxygenators function and be able to target our paO_2s

We can be prepared before CPB