Advances in Respiratory Management in the ICU

David Bihari
Intensive Care Physician
Lismore Base & Prince of Wales Hospitals
The Power of Prayer

God, grant us the...
Serenity to accept things we cannot change,
Courage to change the things we can, and the
Wisdom to know the difference
Patience for the things that take time
Appreciation for all that we have, and
Tolerance for those with different struggles
Freedom to live beyond the limitations of our past ways, the Ability to feel your love for us and our love for each other and the
Strength to get up and try again even when we feel it is hopeless

Serenity Prayer – Rheinhold Niebuhr 1943
Getting Old – 29 Years in the Game

"I am still at the stage where I get so much joy out of helping the people that of patients' [deaths] hasn't overwhelmed me yet."

LESSONS LEARNED FROM LIFE

The getting
of wisdom

CHARLIE TEO

The neurosurgeon, 65, is

Losing with four decades

in Australia. He has

Losing with four decades

Sitting down with your
dad, that's a time

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Intensive Care – Fiddling Whilst Rome Burns!

Or getting it just right for that patient!
29 years of Intensive Care

- The emergence of SEPSIS as THE disease
  - Which it is not!
    - CAP, urosepsis, intra-abdominal sepsis, meningitis, skin and soft tissue infections, nosocomial infections
- Continuous renal replacement therapy
- CPAP and non-invasive ventilation
- Decline in the use of invasive haemodynamic monitoring
- Fluids and oxygen as drugs
Mortality Related to Severe Sepsis and Septic Shock Among Critically Ill Patients in Australia and New Zealand, 2000-2012

Kirsi-Maija Kaukonen, MD, PhD, EDIC; Michael Bailey, PhD; Satoshi Suzuki, MD; David Pilcher, FCICM; Rinaldo Bellomo, MD, PhD

**IMPORTANCE** Severe sepsis and septic shock are major causes of mortality in intensive care unit (ICU) patients. It is unknown whether progress has been made in decreasing their mortality rate.

**OBJECTIVE** To describe changes in mortality for severe sepsis with and without shock in ICU patients.

**DESIGN, SETTING, AND PARTICIPANTS** Retrospective, observational study from 2000 to 2012 including 101,064 patients with severe sepsis from 171 ICUs with various patient case mix in Australia and New Zealand.

**MAIN OUTCOMES AND MEASURES** Hospital outcome (mortality and discharge to home, to other hospital, or to rehabilitation).
Things do seem to be improving
“Solely the dose determines that a thing is not a poison.”

Sola dosis facit venenum.

Alle Dinge sind Gift und nichts ist ohne Gift, allein die Dosis macht es, dass ein Ding kein Gift ist.

All things are poison and nothing is without poison, only the dosage makes a thing not poison.

—Paracelsus[1]

- Drugs
- Fluids
- Oxygen
The Concept of the J shaped Curve

Dose

Mortality rate %

“Sweet” point
Former Socceroo Steve Herczeg died after catheter connected to oxygen, coroner told

Inquest begins into death of 72-year-old in September at Queen Elizabeth hospital in Adelaide

A former Socceroo died in hospital because his urinary catheter was wrongly connected to an oxygen supply, leading to a burst bladder and collapsed lungs, a coroner has heard.
Oxygen Toxicity

- High concentrations of oxygen can result in the formation of oxygen “free radicals”
  - reactive oxygen species
    - superoxide anion
    - peroxide (hydrogen peroxide)
    - hydroxyl radical
Oxygen Toxicity

• Oxygen is a vasoconstrictor in the systemic circulation (and hypoxia vasodilates)
  – As PaO2 increases above 100 mmHg, artioles vasoconstrict restricting blood flow to tissues
  – Important in stroke (cerebral vasoconstriction) and heart attack (coronary vasoconstriction)

• Remember – the opposite is true in the pulmonary circulation!
  – Hypoxic pulmonary vasoconstriction
The Concept of the J shaped Curve

Arterial Oxygen Tension mmHg

Mortality rate %

“Sweet” point

60 – 100 mm Hg
Evidence for this “Sweet Point”

• Uncontrolled verses controlled oxygen therapy in patients with acute exacerbations of chronic airways obstruction
  – Tasmania, BMJ 2010

• Air verses Oxygen in ST elevation MI (AVOID) study
  – Melbourne, Circulation 2015

• Others – stroke, ROSC post cardiac arrest
Problem of Monitoring

- We do not monitor arterial PO2 at the bedside
- We monitor arterial saturations using pulse oximetry
- 100% saturation means that PaO2 > 120 mmHg

Diagram: 
- Hemoglobin saturation (%) vs. Pressure of oxygen in blood (PO2) (mmHg)
- pH shifts right:
  1. Increased hydrogen ions
  2. Increased CO2
  3. Increased temperature
  4. Increased BPG
Hemoglobin saturation (%)

pH

- 7.6
- 7.4
- 7.2

Shift to right:
1. Increased hydrogen ions
2. Increased CO₂
3. Increased temperature
4. Increased BPG

Sweet point
We are actually living near the bottom of an ocean of air

At sea level, the weight of the air presses on us with a pressure of approximately 14.7 lbs/in².

At higher altitudes, less air means less weight and less pressure. Pressure and density of air decreases with increasing elevation.

Difficult to climb at high altitudes without oxygen

<table>
<thead>
<tr>
<th>fraction of 1 atm</th>
<th>mmHg</th>
<th>average altitude (m)</th>
<th>average altitude (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/100000</td>
<td>96,281.6</td>
<td>1/100000</td>
<td>283,076</td>
</tr>
<tr>
<td>1/10000</td>
<td>69,463.6</td>
<td>1/1000</td>
<td>227,899</td>
</tr>
<tr>
<td>1/1000</td>
<td>48,467.2</td>
<td>1/100</td>
<td>159,013</td>
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<tr>
<td>1/100</td>
<td>30,900.9</td>
<td>1/10</td>
<td>101,381</td>
</tr>
<tr>
<td>1/10</td>
<td>16,131.9</td>
<td>1/1</td>
<td>52,926</td>
</tr>
<tr>
<td>1/3</td>
<td>8,375.8</td>
<td>3/1000</td>
<td>27,480</td>
</tr>
<tr>
<td>1/2</td>
<td>380</td>
<td>5,486.3</td>
<td>18,000</td>
</tr>
<tr>
<td>1</td>
<td>760</td>
<td>0</td>
<td>0</td>
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<tr>
<td>8000 ft – 565 mm HG</td>
<td>PispO2 = 118 mm Hg</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Difficult to climb at high altitudes without oxygen
Arterial Blood Gases and Oxygen Content in Climbers on Mount Everest

Figure 1. Barometric Pressure (Ps) and Partial Pressure of Inspired Oxygen (P_{iO_2}) in Blood Samples Obtained from Subjects Breathing Ambient Air at Various Altitudes between London and the Summit of Mount Everest.

In Panel A, the measurements at the summit are reported from West et al.\textsuperscript{7} The other measurements were performed by the investigators.
Figure 2. Changes in the Arterial Mean Partial Pressure of Oxygen, Oxygen Saturation, Hemoglobin Concentration, and Oxygen Content in Climbers on Mount Everest.

Bars denote standard deviations.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Subject No.</th>
<th>Group Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>pH</td>
<td>7.55</td>
<td>7.45</td>
</tr>
<tr>
<td>PaO\textsubscript{2} (mm Hg) \textsuperscript{†}</td>
<td>29.5</td>
<td>19.1</td>
</tr>
<tr>
<td>PaCO\textsubscript{2} (mm Hg) \textsuperscript{†}</td>
<td>12.3</td>
<td>15.7</td>
</tr>
<tr>
<td>Bicarbonate (mmol/liter) \textsuperscript{‡}</td>
<td>10.5</td>
<td>10.67</td>
</tr>
<tr>
<td>Base excess of blood \textsuperscript{‡}</td>
<td>-6.3</td>
<td>-9.16</td>
</tr>
<tr>
<td>Lactate concentration (mmol/liter)</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>SaO\textsubscript{2} (%) \textsuperscript{‡}</td>
<td>68.1</td>
<td>34.4</td>
</tr>
<tr>
<td>Hemoglobin (g/dl) \textsuperscript{§}</td>
<td>20.2</td>
<td>18.7</td>
</tr>
<tr>
<td>Respiratory exchange ratio \textsuperscript{¶}</td>
<td>0.81</td>
<td>0.74</td>
</tr>
<tr>
<td>PaO\textsubscript{2} — mm Hg\textsuperscript{**}</td>
<td>32.4</td>
<td>26.9</td>
</tr>
<tr>
<td>Alveolar–arterial oxygen difference — mm Hg\textsuperscript{†}</td>
<td>2.89</td>
<td>7.81</td>
</tr>
</tbody>
</table>

* PaCO\textsubscript{2} denotes partial pressure of arterial carbon dioxide, PaO\textsubscript{2} partial pressure of alveolar oxygen, PaO\textsubscript{2} partial pressure of arterial oxygen, and SaO\textsubscript{2} calculated arterial oxygen saturation.
† To convert the values for PaO\textsubscript{2}, PaCO\textsubscript{2}, PaO\textsubscript{2}, and the alveolar–arterial oxygen difference to kilopascals, multiply by 0.1333.
‡ These values were calculated with the use of the algorithms currently approved by the Clinical Laboratory Standards Institute.\textsuperscript{10}
§ The values for hemoglobin are the mean values of measurements obtained at 5300 m (17,388 ft) 9 days before and 8 days after the arterial blood sampling.
¶ The respiratory exchange ratio was measured at an elevation of 7950 m while the subject was resting.
** No measured respiratory exchange ratio was available for this subject; the value was derived from the mean values for the other three subjects.
So why are we aiming for 97 – 100%?

Oxygen in the ICU
Too Much of a Good Thing?

Niall D. Ferguson, MD, MSc

Oxygen gas was discovered and described in the 1770s by Scheele, Priestley, and Lavoisier and shortly thereafter its therapeutic potential for patients with respiratory illness was appreciated. Oxygen has become a mainstay of treatment for acutely ill patients, with emphasis frequently placed on the importance of avoiding hypoxemia. The study patients had
Effect of Conservative vs Conventional Oxygen Therapy on Mortality Among Patients in an Intensive Care Unit
The Oxygen-ICU Randomized Clinical Trial

Massimo Girardis, MD; Stefano Busani, MD; Elisa Damiani, MD; Abele Donati, MD; Laura Rinaldi, MD; Andrea Marudi, MD; Andrea Morelli, MD; Massimo Antonelli, MD; Mervyn Singer, MD, FRCA

IMPORTANT Despite suggestions of potential harm from unnecessary oxygen therapy, critically ill patients spend substantial periods in a hyperoxemic state. A strategy of controlled arterial oxygenation is thus rational but has not been validated in clinical practice.

OBJECTIVE To assess whether a conservative protocol for oxygen supplementation could improve outcomes in patients admitted to intensive care units (ICUs).

DESIGN, SETTING, AND PATIENTS Oxygen-ICU was a single-center, open-label, randomized clinical trial conducted from March 2010 to October 2012 that included all adults admitted with an expected length of stay of 72 hours or longer to the medical-surgical ICU of Modena University Hospital, Italy. The originally planned sample size was 660 patients, but the study was stopped early due to difficulties in enrollment after inclusion of 480 patients.
Patients were randomly assigned to receive oxygen therapy to maintain $\text{Pao}_2$ between 70 and 100 mm Hg or arterial oxyhemoglobin saturation ($\text{SpO}_2$) between 94% and 98% (conservative group) or, according to standard ICU practice, to allow $\text{Pao}_2$ values up to 150 mm Hg or $\text{SpO}_2$ values between 97% and 100% (conventional control group).

**MAIN OUTCOMES AND MEASURES** The primary outcome was ICU mortality. Secondary outcomes included occurrence of new organ failure and infection 48 hours or more after ICU admission.

**RESULTS** A total of 434 patients (median age, 64 years; 188 [43.3%] women) received conventional ($n = 218$) or conservative ($n = 216$) oxygen therapy and were included in the modified intent-to-treat analysis. Daily time-weighted $\text{Pao}_2$ averages during the ICU stay were significantly higher ($P < .001$) in the conventional group (median $\text{Pao}_2$, 102 mm Hg [IQR, 88-116]) vs the conservative group (median $\text{Pao}_2$, 87 mm Hg [IQR, 79-97]). Mortality was lower in the conservative oxygen therapy group. The conservative group had fewer episodes of shock, liver failure, and bacteremia.

<table>
<thead>
<tr>
<th>Oxygen Therapy, No. (%)</th>
<th>Conservation (n = 216)</th>
<th>Conventional (n = 218)</th>
<th>Absolute Risk Reduction (95% CI)</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary outcome</td>
<td></td>
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<tr>
<td>ICU mortality</td>
<td>25 (11.6)</td>
<td>44 (20.2)</td>
<td>0.086 (0.017-0.150)</td>
<td>.01</td>
</tr>
<tr>
<td>Secondary outcomes</td>
<td></td>
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<tr>
<td>Shock</td>
<td>8 (3.7)</td>
<td>23 (10.6)</td>
<td>0.068 (0.020-0.120)</td>
<td>.006</td>
</tr>
<tr>
<td>Liver failure</td>
<td>4 (1.9)</td>
<td>14 (6.4)</td>
<td>0.046 (0.008-0.088)</td>
<td>.02</td>
</tr>
<tr>
<td>Bacteremia</td>
<td>11 (5.1)</td>
<td>22 (10.1)</td>
<td>0.050 (0.000-0.090)</td>
<td>.049</td>
</tr>
</tbody>
</table>
Figure 2. Probability of Survival From Study Inclusion (Day 0) Through Day 60 for Patients in the Conservative and Conventional Oxygen Strategy Groups

Patients discharged alive from the hospital were considered to have survived, and their median follow-up was 22 days for the conservative group (interquartile range, 13-37) and 24 days for the conventional group (interquartile range, 15-35).
CPAP & Non-Invasive Ventilation

• CPAP is a form of respiratory support
  – Opens up the lung – increases FRC
  – Improves arterial oxygenation
  – Reduces work of breathing
  – Reduces “preload” and “afterload”

• BiPAP is a form of ventilatory support
  – Does all of the above
  – Increase tidal volume and alveolar ventilation
  – Reduces arterial PCO2
High Flow Oxygen Therapy
High Flow Oxygen Therapy

Oxygen and Air Blender

HFT Nasal Cannula

Temperature Sensor

Humidifier - Heater

Heated Delivery Tube
High Flow Nasal Oxygen Therapy

Use in place of all face mask or nasal cannula oxygen delivery devices
• Use for rest breaks during noninvasive ventilation
• Use to wean patients off invasive and noninvasive ventilation
• Use for respiratory support with or without supplemental oxygen

Great for “type 1” respiratory failure (low PaO2 / sats)

No good for patients with CO2 retention
Steroids and Community Aquired Pneumonia

• Severe CAP requiring admission to hospital usually treated with
  – Ceftriaxone and azithromycin

• Several recent studies in the last 5 years suggest that steroids hasten resolution of CAP and reduces the risk of deterioration
  – ICU admission, requirement for ventilation

• Dexamethasone, prednisolone, hydrocortisone
Other Advances in Respiratory Management

• The right antibiotic in the right dose (big) at the right time (early) saves lives
• Non-invasive ventilation (high quality) with the right mask
• Limit the tidal volume (6 mL/kg) and the driving pressure (<18 cm H2O)
• Nourish the patient (physical and spiritual)
• Early mobilisation
Crap-trapping
William A Silverman, Lancet 1997; 349: 1471

• Survival in the age of information overload
  – Surviving the tyranny of “Evidence Based Medicine” in the ICU

• Continuing struggle against the “veneration of crap”!

• In order to survive, the novelist Ernest Hemingway once observed
  – “a person must have a built-in, shockproof crap detector”