Anesthesia Clinical Tutor and Calculator
Version 3.0
Tutorial

*Note: Both the PPC and Palm versions are identical in function but screens will differ in appearance

This a support document for Users of ACTc
It is the desire of the developers of ACTc to educate & inform present and future colleagues in the science of anesthesia. ACTc is meant to enhance the understanding of Anesthesia, and is never meant to replace expert clinical judgment by qualified and trained anesthesia professionals.

Use/misuse of this product is the responsibility of each individual user. ACTc is an intuitive collection of tools and is not meant to be all inclusive or comprehensive. It is meant to act as an adjunct to existing anesthesia references.
Each screen contains a help section, “I”, or an “EYE” icon which will explain the science background of each screen, hence it is advised to completely read and understand these prior to use.

All users are recommended to review this document and the referenced material mentioned within for accuracy and appropriateness.
Anesthesia is an art and science and only professionally trained & licensed clinicians can make appropriate patient care decisions. Gasshead take no responsibility in the use or misuse of this educational publication.

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Email any comments to: General@gasshead.com

GASSHEAD LLC
PO Box 897
Lakeside, MT  59922-0897

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Acknowledgements

The development of Anesthesia Clinical Tutor and Calculator represents an amalgam of a sincere desire to combine my experience and understanding of anesthesia science, a passion for education, and a bit of an obsession with computers and small technological devices.

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Thanks also to my development team at Endeavour Software Technologies. Avinash, Jayandra, Nidhi, Jesus, Youvraj, and Madhan…All of you are miracle workers. It was a pleasure working with such a talented team.

Finally, thanks to all the researchers and educators in anesthesia whose endeavors keep enhancing our understanding to this wonderful and challenging field. It sharpens our practice, tempers our vision, and ultimately improves the daily care of our patients.

Anthony T Young
Installation and Activation of ACTc

Uninstall all previous versions from both your hand held and Desktop

PPC users must install via their Active sync window
  Goto -> Tools-> Add/Remove->Highlight Gasshead/ACTc->Click remove
  Confirm uninstallation on your PDA
    Goto settings-> Systems-> Remove Programs
  Remove Any Gasshead or ACTc programs
PALM
  Delete 2 files – ACTc and Gasshead

1. Download and install from http://www.gasshead.com

PPC Users (Windows)
http://www.gasshead.com/Installers/Trial_versions/ACTc_TrialVersionPPC.exe
Palm Users (Windows)
http://www.gasshead.com/Installers/Trial_versions/ACTc_TrialVersion.exe
PPC Users (MAC)
http://www.gasshead.com/Installers/Trial_versions/ACTcPPCApplication.tar
Palm Users (MAC)
http://www.gasshead.com/Installers/Trial_versions/ACTcPalmApplication.tar

2. Trial the program to your satisfaction
3. Purchase ACTc at this page: https://www.gasshead.com/purchase.aspx
   Complete the payment form completely – at a point you will be asked for the
   Product ID
    A. Start your PDA
       - Start the ACTc program
       - Click on the “Purchase button” to obtain the Product ID and type
         it in Exactly on the on-line form
       - Click OK on your PDA

       Once the process has been confirmed and completed you will be
given an Activation Code.

       To Activate:
       - Click on the “Activate” button on your ACTc start up screen and
         type in the activation code exactly as provided

If you have a promotion code, goto to this page:
https://www.gasshead.com/frmPurchaseViaPromo_Key.aspx
- Input the promo code provided on your gift certificate (case sensitive)
- Complete the form completely – at a point you will be asked for the **Product ID**

A. Start your PDA
   - Start the ACTc program
   - Click on the “Purchase button” to obtain the **Product ID** and type it in
   - Exactly on the online form
   - Click OK on your PDA

Once the process has been confirmed and completed you will be given an Activation Code.

To Activate:

- Click on the “Activate” button on your ACTc start up screen and type in the activation code exactly as provided
Anesthesia Clinical Tutor and Calculator (ACTc) - Introduction

ACTc is a collection of tools and is not meant to be all inclusive or comprehensive. It is meant to used as a adjunct to existing anesthesia references. For all good practitioners in training will utilize a number of sources – both in written form (references, research publications, scholarly articles, etc…) and by clinical guides (attendings, clinical faculty, and peers). ACTc is built to mimic clinical thought flow and provide an interactive feedback on data each anesthesia provider inputs.

Each patient has specific presentation that must be accounted, hence after a thorough focused anesthesia patient assessment, each clinician mentally “sets up” by determining the anesthetic plan and operative needs to ensure the safest course. This encompasses accounting for patient variables and perioperative needs:

- Pathologic considerations and anesthetic implications
- Fluid and Blood requirements
- Specific operative demands on patient stability
  - Possible contingent actions for issues related to operation and or anesthetic technique
- Pharmacologic intervention
- Monitoring requirement
- Positioning implications
- And post operative needs / concerns

Quick Start

Starting at the Patient data screen

On the Patient data screen, intuitive flow helps one understand “setting up.”

1) Selecting the appropriate “Patient type” plays a large part in a multitude of calculations: estimating blood requirements, fluid volumes, drug calculations, airway needs, etc…hence select the appropriate patient type: Newborn (<30 days) infant (1 – 12 months), Child, Adult Male or Female, and Geriatric Male or Female.
2) For Every Anesthetist the following inputs are natural and establishes the base for many calculations and helps anticipate needs.

3) The Snap Shot screen pre-selects common values and drug selections for a multitude of cases. Most importantly, it allows each user to customize each screen for their individual practice styles.

4) Finally, based on patient type, airway (ETT or LMA) selections/guides are generated at the bottom.

5) For Pediatrics categories, the 50% percentile Vital signs are also shown, separated into age groups and genders.

6) Now, in appropriate sections – weight and patient type considerations are now inputted to generate specific calculations as you navigate to these other screens.

7) Note – an adult patient type must be selected to review spinal and epidural data.

**Patient Data Screen**

The surgical schedule dictates every anesthetist day. The ability to process and plan the course of that day hinges upon one's ability to properly plan and anticipate surgical demands balanced upon patient presentation and needs.

Naturally, one looks at the procedures (which may or may not hint at the patient population you can expect to encounter) and then at the age of your patients. Many times, without meeting the patients, one can delineate some basic core requirements (potential fluid needs, airway needs & equipment, and minimum drug requirements). This is preemptive to a patient focused assessment.
On the Patient data screen, it allows you to start intuitively “setting up

calculations:

1) Patient type plays a large part in a multitude of
calculations: estimating blood requirements, fluid
volumes, drug calculations, airway needs, etc…hence
select the appropriate patient type: Newborn (<30
days) infant (1 – 12 months), Child, Adult Male or
Female, and Geriatric Male or Female.
The constants used in ACTc for EBV (cc * kg) are as follows: (Newborn 90, Infant 85,
Child 80, Adult Male 75, Adult Female 70, Geriatric Male 70, Geriatric Female 65)

2) The default value of Hours NPO is 12 (which can be changed). This number is used to
help determine NPO deficits on the are determined by the hours NPO multiplied by the 4-
2-1 rule

- 4 cc/kg/hr per first 10 kg
- 2 cc/kg/hr for each kg between 10 – 20
- 1 cc/kg/hr for each kg 21 and greater[1, 2]

Note: that in pediatric patients with dehydration who
cannot tolerate oral re-hydration:
- 40 cc/kg of LR over 1 – 2 hours should be
administered (moderate dehydration).
- For severe dehydration, LR or NS made be used.
  o If skin turgor, alertness, or pulse do not return to normal with the above
dose, an additional dose of 20-40 mL/kg may be given - over 1-2 hours.[3]

In Adults with severe dehydration, presenting with hypovolemia
- Rehydration with sufficient fluid to restore mean arterial pressure, heart rate and
filling pressure (preload or CVP) prior to induction is advisable.
- If time allows, establishing normal urine output is also advisable.[4]

3) Evaporative Constants are based on degree of exposed or manipulated tissue(s). This
hourly estimation varies from source to source but is ultimately up to each provider to
determine. A rough guideline that can be used is:
- Minimal trauma (0 – 4 cc/kg/hr Arthroscopic, Laparoscopic, Small incision)
- Moderate trauma (4 – 6 cc/kg/hr Hystectomies, Thorocotomy)
- Severe trauma (6 + cc/kg/hr Bowels, Large Abdominal Cases, Burns, Aortas,
  Open Chests, Trauma)[2, 5]
Based on this, you can select Evaporative ranges from 1 – 15 ml/ kg/hr in ACTc

4) The bottom of the screen provides the user with either LMA or ETT selection information for the specific patient type they have selected. These selections are based on the following criteria:

- LMA (courtesy of LMA North America, Inc)[6]

Table 4: LMA™ Airway Selection Guidelines

<table>
<thead>
<tr>
<th>LMA™ Airway Size</th>
<th>Patient Size</th>
<th>Maximum Cuff Inflation Volumes (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Neonates/Infants up to 5 kg</td>
<td>4 mL</td>
</tr>
<tr>
<td>1 ve</td>
<td>Infants 5-10 kg</td>
<td>7 mL</td>
</tr>
<tr>
<td>2</td>
<td>Infants/Children 10-20 kg</td>
<td>10 mL</td>
</tr>
<tr>
<td>2 ve</td>
<td>Children 20-30 kg</td>
<td>14 mL</td>
</tr>
<tr>
<td>3</td>
<td>Children 30-50 kg</td>
<td>20 mL</td>
</tr>
<tr>
<td>4</td>
<td>Adults 50-70 kg</td>
<td>30 mL</td>
</tr>
<tr>
<td>5</td>
<td>Adults 70-100 kg</td>
<td>40 mL</td>
</tr>
<tr>
<td>6</td>
<td>Adults &gt;100 kg</td>
<td>50 mL</td>
</tr>
</tbody>
</table>

*These are maximum clinical volumes that should never be exceeded. It is recommended the cuff be inflated to 20 cm Hg intracuff pressure.

ETT selection for Adults & Geriatric are selected based on the following table

<table>
<thead>
<tr>
<th>Wt or Age</th>
<th>ETT</th>
<th>Average Dist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult Female</td>
<td>6.5 - 7.5</td>
<td>19 - 24 cm</td>
</tr>
<tr>
<td>Adult Male</td>
<td>7.0 - 9.0</td>
<td>20 - 24 cm</td>
</tr>
<tr>
<td>Geriatric Female</td>
<td>6.5 - 7.5</td>
<td>19 - 24 cm</td>
</tr>
<tr>
<td>Geriatric Male</td>
<td>7.0 - 9.0</td>
<td>20 - 24 cm</td>
</tr>
</tbody>
</table>

- For Pediatric ETT selection is based on a combination of several guidelines. The appropriate selection is automated values are based on the following criteria:
The image contains a page from a document discussing guidelines for pediatric endotracheal tube (ETT) selection. The page outlines recommended guidelines based on weight, age, and gestational age. It includes a table with specific ETT sizes and recommendations for different age groups and weight categories. The document also provides additional notes and guidelines for selecting the appropriate tube size, including alternative methods and considerations for tube selection. The text is structured in a clear, educational format, aiming to provide medical professionals with comprehensive information on ETT selection for pediatric patients.
If > then 44 weeks gestational age use the following calculation
3 x ETT size
If <44 weeks gestational age: 6 / KG[7]
An alternative to this is: 12 + Age (years)/2[2, 7, 11, 12]

Snap Shot

- All clinicians have specific preferences for specific cases.
- ACTc allows for each user to build their own “Snap Shot”
- New Profiles are entered using the drop down arrow new to “Standard”
- Then desired data is selected and positioned on the screen using the “Up,” “Down,” and “Remove” buttons.
- If a change is desired in a specific Profile – Select the Profile and click on “Customize This Screen”
  o Add the desired data by selecting the “Add” button and its position on the screen is controlled by highlighting it and clicking up or down.
  o Click “back when done”
Airway

Above all, anticipate and be prepared. A notable quote from Morgan and Mikhail is “It must be stress that because no examination technique is fool-proof and the signs of a difficult airway may be subtle…always be prepared for unanticipated difficulties”[1]

Airway concerns are central to any anesthetic. Primary assessment and history assists the clinician to proactively plan for airway concerns.

ACTc provides core understanding in airway management and assessment.

On Airway Screen

Two Menu selections are available. Scrolling the buttons at the bottom right and the “EVAL” button allows you to review the following data:

**ETT Chart**

<table>
<thead>
<tr>
<th>Wt or Age</th>
<th>ETT</th>
<th>AvDist</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kg</td>
<td>2.5 ncuf</td>
<td>7 cm</td>
</tr>
<tr>
<td>1.5 kg</td>
<td>3.0 ncuf</td>
<td>7.5 cm</td>
</tr>
<tr>
<td>2 kg</td>
<td>3.0 ncuf</td>
<td>8 cm</td>
</tr>
<tr>
<td>3 kg (preterm)</td>
<td>3.0 ncuf</td>
<td>9 cm</td>
</tr>
<tr>
<td>3 kg (term)</td>
<td>3.0 ncuf</td>
<td>10 cm</td>
</tr>
<tr>
<td>6 -12 mon</td>
<td>3.0 ncuf</td>
<td>11 cm</td>
</tr>
<tr>
<td>12 - 18 mon</td>
<td>3.5 ncuf</td>
<td>12 cm</td>
</tr>
<tr>
<td>18 -36 mo</td>
<td>4.0 ncuf</td>
<td>13 cm</td>
</tr>
<tr>
<td>3 - 5 yr</td>
<td>4.5 ncuf</td>
<td>14 cm</td>
</tr>
<tr>
<td>5 - 6 yr</td>
<td>5.0 cuf</td>
<td>15 cm</td>
</tr>
</tbody>
</table>
ETT

<table>
<thead>
<tr>
<th>Wt or Age</th>
<th>ETT</th>
<th>AvDist</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 - 8 yr</td>
<td>5.5 cuf</td>
<td>16 cm</td>
</tr>
<tr>
<td>8 - 10 yr</td>
<td>6.0 cuf</td>
<td>18 cm</td>
</tr>
<tr>
<td>11 - 12 yr</td>
<td>6.5 cuf</td>
<td>18 cm</td>
</tr>
<tr>
<td>Adult Female</td>
<td>6.5 - 7.5</td>
<td>19 - 24 cm</td>
</tr>
<tr>
<td>Adult Male</td>
<td>7.0 - 9.0</td>
<td>20 - 24 cm</td>
</tr>
<tr>
<td>Geriatric Female</td>
<td>6.5 - 7.5</td>
<td>19 - 24 cm</td>
</tr>
<tr>
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</tbody>
</table>

LMA Chart – (courtesy of LMA North America, Inc)

Table 4: LMA™ Airway Selection Guidelines

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<td>Neonates/Infants up to 5 kg</td>
<td>4 mL</td>
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<tr>
<td>1½</td>
<td>Infants 5-10 kg</td>
<td>7 mL</td>
</tr>
<tr>
<td>2</td>
<td>Infants/Children 10-20 kg</td>
<td>10 mL</td>
</tr>
<tr>
<td>2½</td>
<td>Children 20-30 kg</td>
<td>14 mL</td>
</tr>
<tr>
<td>3</td>
<td>Children 30-50 kg</td>
<td>20 mL</td>
</tr>
<tr>
<td>4</td>
<td>Adults 50-70 kg</td>
<td>30 mL</td>
</tr>
<tr>
<td>5</td>
<td>Adults 70-100 kg</td>
<td>40 mL</td>
</tr>
<tr>
<td>6</td>
<td>Adults &gt;100 kg</td>
<td>50 mL</td>
</tr>
</tbody>
</table>

*There are maximum clinical volumes that should never be exceeded. It is recommended the cuff be inflated to 20 cm H<sub>2</sub>O intracuff pressure.

- Difficult Mask considerations
- Cuffed vs. Uncuffed
- Axis Alignment Diagrams
- LEMON Assessment Guide
- Mallampati Diagrams

The following table is also added to the Pediatric Vital Signs table

<table>
<thead>
<tr>
<th>Variable</th>
<th>NB</th>
<th>1 yo</th>
<th>3 yo</th>
<th>5 yo</th>
<th>12 yo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resp. Rate</td>
<td>40 - 60</td>
<td>20 - 30</td>
<td>18 - 25</td>
<td>18 - 25</td>
<td>20</td>
</tr>
<tr>
<td>TV (cc/kg)</td>
<td>10 - 12</td>
<td>10 - 12</td>
<td>10 - 12</td>
<td>10 - 12</td>
<td>10 - 12</td>
</tr>
</tbody>
</table>

Table 2[1]

If the “?” next to the airway is clicked then the following is shown:
Pediatric ETT selection is as follows:

- PALS recommended guidelines up to age 2 (AHA)
- Tube size for children = $16 + \frac{\text{Age (years)}}{4}$ or $\frac{\text{AGE}}{4} + 4$ (AHA)[7, 10]

Another Alternative by Penlington for children less than 6 years[10, 11]:

- Age (years)/3 + 3.75
- 6 and greater : Age(years)/4 + 4.5

The easiest technique but is often unreliable is the use of the little finger to determine internal diameter of which ETT to be used.

Pediatric Depth determination

- If > then 44 weeks gestational age use the following calculation
  - 3 x ETT size

- If <44 weeks gestational age: $\frac{6}{\text{KG}}[7]$

- An alternative to this is : $12 + \frac{\text{Age (years)}}{2}[2, 7, 10, 11]$
- Another alternative:
  - ETT tip should be advanced until the tip is positioned at least 2 cm below vocal cords
    - Basic Rules:
      - 1 kg = 7 at lips
      - 2 kg = 8 at lips
      - 3 kg = 9 at lips
      - 4 kg 10 cm at gums for mid tracheal placement
  - Or try a main-stem approach where tip is advanced until BS can only be heard only in right lung fields (diminished on the Left) and then pull ETT back 2 - 3 cm until equal breath sounds are heard
  - Optional: CXR
  - Generally: distance = 30 times internal diameter of ETT should be distance at the teeth[9]

- For nasal distances, Add 2 - 3 cm for nasal depth[1]

*Note: If the “?” next to the LMA section is clicked then the data from fig 6 is shown*
**Mallampati screen**

Based on Mallampati et determination of visualization of specific structures and modified by Samsoon and Young[13]. Refer to Figures below for graphical guide.

The patient sits upright with the head in the neutral position.

The patient is asked to open the mouth as widely as possible and to protrude the tongue to the maximum.

The observer sits opposite at eye level and with a light source inspects the pharyngeal structures – Uvula, tonsilar pillars, fauces, and soft palate (Refer to below for graphical guide). Other factors to consider:

- Limited Neck Mobility <35 degrees
- Obesity
- Anatomical deformities secondary to congenital issues, trauma, disease, or surgical history
- Small oral opening[13-15]

**LEMON screen**

The L.E.M.O.N method, as described by Ron Walls, is another method for assessing potential airway issues but can be difficult to use in certain patient presenting for resuscitation. [16-18]

- Look externally
- Evaluate the 3-3-2 rule

![LEMON Method](images.png)

**Figure 8 L.E.M.O.N. by Walls[17]/Images by Gasshead**
Mallampati

Positioning First

![Positioning Diagram](image)

**Figure 9** Images by Gasshead, Instructions by Mallampati[15]

<table>
<thead>
<tr>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft Palate</td>
<td>Soft Palate</td>
<td>Soft Palate</td>
<td>Soft Palate</td>
</tr>
<tr>
<td>Uvula</td>
<td>Uvula</td>
<td>Base of Uvula</td>
<td>not visible</td>
</tr>
<tr>
<td>Fauces</td>
<td>Fauces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pillars</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 10** Images by Gasshead, Instructions by Mallampati[15]

Obstruction

Neck mobility

![Obstruction Diagram](image)

**Figure 11** L.E.M.O.N. by Walls[17], Images by Gasshead

O = Obstruction - Are there any obstructions that will make ventilation and laryngoscopy difficult?

N = Neck Mobility - have the patient place their chin to their chest & extend their head as much as possible.
**Cuff vs Uncuffed**

Pediatric Peak Pressures and use of Cuffed vs. Uncuffed ETT:

Avoiding tracheal damage by proper selection of ETT and monitoring peak airway pressures in children is paramount. Though no source in complete agreement, a small air leak at peak inflation pressure (PIP) of 20–30 cm H2O should be acceptable (which can vary based on provider, pulmonary compliance, and procedure). Also in flux is the issue of cuffed vs. uncuffed ETT. [12, 19, 20]

Traditionally, it has been the norm to recommend the use of cuffed ETT for children older than 8 years old. But even this is being challenged. Gavin et al. is quoted “…this advantage (referring to un-cuffed tubes) does not hold for ventilated patients, for whom ventilator settings can be adjusted to provide optimal airflow. Longer duration of intubation and a poorly fitted ETT are risk factors for mucosal damage, whether the ETT is cuffed or uncuffed.” [21]

**Axes screen**

“?” brings up the following text

The concept of aligning the “Three Axes” via the sniff position has been institutionalized in all practitioners thinking. Yet recent studies have brought to question it’s true ability to align themselves on a single plane and or improve actual glottic view. At minimum, direct laryngoscopy requires force, manipulation (active position changes to head/neck), and or varying degrees of the Sellick manoeuvre (cricoid pressure). Regardless, an appreciation of the applied geometry helps in visualizing what we are attempting by direct manipulation.

Proper positioning is a vital part of a dynamic process. In practice, it is extremely helpful to appreciate and visualize anatomical changes that can help us achieve efficient airway placement that minimizes its impact on our patients.[16, 22-24]
Difficult Mask

Langeron O. et al in 2000 was able to identify 5 independent variables that help identify potential difficult mask ventilation.

1. Presence of a beard
2. Body-mass index greater than 26 kg/m²
3. History of regular snoring
4. Edentulousness
5. Age older than 55

Interestingly, subjective evaluation identified only 17% of the aforementioned variables. Langeron found that if a patient was difficult to mask, there was also a 4 – 12 time potential for a difficult / impossible intubation, respectively.[26]

Magboul condensed the finding with the word OBESE

Obese Bearded Elderly Snorers Edentulous[16]
Kheterpal, S. et al found similar findings adding Mallampati classification III or IV, age of 57 yr or older, severely limited jaw protrusion, abnormal neck anatomy, & sleep apnea also contributed.[27]

**Fluid Screen**

Important considerations of perioperative fluid replacement guidelines as automated in ACTc are as follows.

The fluid screen provides a break down of the different values consisting of the hourly totals for fluid administration. It does not however account for blood loss. The screen layout is self explanatory with an hourly total running left to right at the middle/bottom of the screen. Scroll down for an explanation on the hourly totals.

**Total Fluid Breakdown**

Total fluids required for the anesthetic are as follows:

- NPO deficit replacement
- Maintenance Fluid
- Evaporative Losses
- and Blood Replacement. (* not account for in this screen) [1]

The Hourly Maintenance Fluid will calculate the values using the formula.

Calculated using WT in KG
- For KG 1 – 10 kg add 4cc for each kg
- For KG 11 – 20 kg add 2cc for each kg
- For KG > 21 kg add 1cc for each kg[5]
The **Hourly Evaporative Rate** will be calculated as:

- Calculated by KG x User Defined Evaporative Constants
- Evaporative Constants are based on degree of exposed or manipulated tissue(s).

This hourly estimation varies from source to source but is ultimately up to each provider to determine. A rough guideline to use is:

- Minimal trauma (0 – 4 cc/kg/hr Arthroscopic, Laparoscopic, Small incision)
- Moderate trauma (4 – 6 cc/kg/hr Hysterectomies, Thorocotomy)
- Severe trauma (6 + cc/kg/hr Bowels, Large Abdominal Cases, Burns, Aortas, Open Chests, Trauma)[2, 5, 28]

The **NPO Deficit** is calculated by **Hours NPO** multiplied by **Hourly Maintenance Fluid**.

Note: that in pediatric patients with dehydration who cannot tolerate oral re-hydration:

- 40 cc/kg of LR over 1 – 2 hours should be administered (moderate dehydration).
- For severe dehydration, LR or NS made be used.
  - If skin turgor, alertness, or pulse do not return to normal with the above dose, an additional dose of 20-40 mL/kg may be given - over 1-2 hours.[3]

In Adults with severe dehydration, presenting with hypovolemia:

- Rehydration with sufficient fluid to restore mean arterial pressure, heart rate and filling pressure (preload or CVP) prior to induction is advisable.
- If time allows, establishing normal urine output is also advisable.[4]

The **Total Hourly Fluids** is calculated by adding the **Hourly Fluids** and **Hourly Evaporative Rate**.

**Intraoperative variability and fluids**

Several preoperative predictors have been identified for intraoperative hemodynamic variability/instability.

- Preoperative mean arterial pressure (MAP) greater than or equal to 110
- Ability of walking distance of less than 400 m (poor exercise tolerance)
- Plasma volume less than 3000 cc [29]
• The presence of HTN and use of combined spinal epidural techniques[30]
• Pre-existing HTN
  o Severe decreases in BP post induction secondary to volume contracted state[28]
• Elderly
  o Responds to anesthetics with greater degree (compared to younger patients) of hypotension and blood pressure variations during anesthesia.
  o Have a higher sympathetic tone resulting in greater degrees of hypotension.
  o Anesthesia decreases in vascular resistance, contractility, and heart rate.[31]

Due to the volume contracted state that HTN can have on normal fluid status and the resulting rapid decrease in BP after an induction of general anesthesia, appropriate fluid loading can mitigate a very exciting (but unnecessary post induction time) but this must be balanced with the potential issues of fluid loading in patients with limited cardiac functioning and renal reserve.

To offset the potential drop in BP post-induction, ¾ o the preoperative deficits compared to ½ of preoperative deficits should be given prior to induction

**Fluid totals in ACTc**

In ACTc - there is an option of adjusting for preloading for patients with and without HTN.

If the Box is checked:

❖ The “Pre Op” Box value is equal to .75 of the NPO Deficit (3/4 of the NPO deficit should be given prior to induction and the remainder of the deficit given over the next 2 hours in addition to hourly maintenance and evaporative rates

❖ In the “1st Hour” box value is equal to the Value from the “Pre Op Box” + Hourly Fluid Maintenance + Hourly Evaporative Rate + .125 * the NPO deficit

❖ The “2nd Hour” box value is equal to the Value from the “1st Hour” + Hourly Fluid Maintenance + Hourly Evaporative Rate + .125 * the NPO deficit
The “3rd Hour” box value is equal to the Value from the “2nd Hour” + Hourly Fluid Maintenance + Hourly Evaporative Rate
And in the same way up to 24 hours
And if the user did not checked it than the ongoing picture is
The “Pre Op” Box value is equal to .5 of the NPO Deficit
The “1st Hour” box value is equal to the Value from the “Pre Op Box” + Hourly Fluid Maintenance + Hourly Evaporative Rate + .25 * the NPO deficit
The “2nd Hour” box value is equal to the Value from the “1st Hour” + Hourly Fluid Maintenance + Hourly Evaporative Rate + .25 * the NPO deficit
The “3rd Hour” box value is equal to the Value from the “2nd Hour” + Hourly Fluid Maintenance + Hourly Evaporative Rate
And in the same way up to 24 hours

Blood Screen

Virtually every surgical procedure has a potential for blood loss. Hence each clinician must be aware of lower thresholds limits and the variables that can impact them, which if met, will require action. Additionally, open communication about blood replacement strategies with the surgeon will help clarify perioperative needs and postoperative management / follow-up.

Steps for preparation:

1. If high risk or probability for transfusion – order blood ahead of time (anticipate )
   a. The amount is based on starting lab values and anticipated intraoperative loss
   b. Should include an appreciation/assessment of current anticoagulant state.
2. Determine Estimated Blood volume (EBV - see below)
3. Determine starting and ending points (HCT) for your patient (based on recent lab values if possible)
   o Trigger Points for transfusions are controversial and a universal point is generally not recommended.[5]
   o **General recommendations and Observations**[5, 28, 32]:
     - In healthy patients, a HCT of 21 – 30% (Hemoglobin 7 – 10 g/dl) can be tolerated
     - Transfusions for hemoglobin greater than 10 g/dl are rarely indicated
     - The risk for allowing low hemoglobin of between 6 – 10 g/dl must be weighted against potential complications of inadequate oxygenation
     - For HCT Under 21% - Cardiac output increases to maintain oxygen delivery.
       - This can be detrimental to elderly patients, hence patients with cardiopulmonary alterations have higher minimums
       - Generally, a minimal HCT of 30% is acceptable
   o Some useful guidelines for potential “trigger points” for transfusion[5]:
     - If Blood loss greater than 20% of blood volume
     - If Hemoglobin is less than 8 g/dl
     - If Hemoglobin is less than 10 g/dl with major disease (cardiopulmonary)
     - If Hemoglobin is less than 12 g/dl in a ventilator dependent patient
4. Calculate Allowable Blood Loss (ABL- see below)
5. As blood loss occurs, replace by crystalloids or colloids or blood (based on surgical evolution / needs, patient response to loss, & availability)
- 3cc crystalloids per 1 cc Blood loss
- 1 cc colloid per 1 cc Blood loss
- Predetermine (patient and case specific) at which loss threshold you will:
  - replace with strictly crystalloids
  - move on to colloids
  - order/set up blood/ order confirming lab studies
  - transfuse blood
  - send coag studies

**Points to ponder**

There is an ongoing controversy on set guidelines for the use of colloids vs. crystalloids with supporting evidence with both and wet vs. dry strategies with issues surrounding[33-48]:

- Cardiopulmonary functioning
- Hormonal Cardiac responses
- Postoperative symptomatology
- Time to discharge
- Wound healing
- GI functioning
- Acidosis (Hyperchloremic)

Hence, review of current literature is highly recommended.

A suggested strategy would be to transfuse to a 20% loss with a combination of crystalloid (LR) and colloids

- Exception in Bowel Surgery where limiting fluids is

![Figure 15 Blood Screen](image)
advisable[28, 49]

- See above for possible trigger point strategy.

On the Blood Screen, a number of blood volume calculations are found using the following:

- The value of Starting HCT will be by Default of 40 (changeable).
- The value of Ending HCT will be by Default 30 (changeable).
- EBV (Estimated Blood Volume). Is determined by patient category * by the Patient’s weight (in KG). Categories as follows:
  - If Newborn then KG multiplied by 90
  - If Infant then KG multiplied by 85
  - If Child then KG multiplied by 80
  - If Adult Male then KG multiplied by 75
  - If Adult Female then KG multiplied by 70
  - If Geriatric Male then KG multiplied by 70
  - If Geriatric Female then KG multiplied by 65

Estimating Blood loss, as accurately as possible, helps guide many clinicians. This does not replace confirming loss with lab tests and constant discussions with the surgeon about his/her anticipated ongoing surgical losses. In addition to loss in the suction canisters remember that if saturated:

- Dry sponges (4 x4) holds @ 10 cc of blood
- Dry Ray techs @ 10 – 20 cc of blood
- Dry Lap sponges @ 100 cc of blood[28]

- ABL (Allowable blood loss) will be calculated using the formula: \[ ABL = EBV \times \frac{(Starting\ HCT - \ End of HCT)}{Starting\ HCT} \]
Possible Current HCT will be calculated using the formula:

- **Possible HCT = Starting HCT – (starting HCT x (Current Blood Loss / EBV))**

Possible Current HCT = Starting HCT – \[ \text{Starting HCT} \times \left( \frac{\text{Current Blood Loss}}{\text{EBV}} \right) \]

**Incremental Loss**

- Based on the above calculation but when subtracted from the starting HCT it shows the increment of HCT decrease for that Current Blood Loss at a starting HCT compared to the EBV
- Equation = Starting HCT – Possible Current HCT
- Most Clinicians track EBL in increments (i.e. for Adults: 50, 100, 200, 300 ml – for it is hard to account for every ml of blood loss)
  - Try 50, 100, 200, or 300 as values in “Current blood loss “ in the equation above to see what HCT change would occur at the different ml of blood loss
  - Pediatric values are significantly less and allowances must be made in light of their smaller volumes
    - Tracking at 100 plus increments for blood loss would not be recommended

**Whole Blood CC** is calculated by the formula:

- **Whole Blood CC = EBV x ( (Transfuse to HCT – Current HCT) / 35) **
  - Where 35 is the average HCT of the Whole blood
  - Where Transfuse to HCT is always greater than Current HCT
Whole Blood Units needed = Whole Blood in cc divided by 500
- Where 500 = average volume in one unit of whole Blood

PRBC cc needed will be calculated by the formula

PRBC cc = EBV x ((Transfuse to HCT – Current HCT)/70)[50]
- Where 70 is the average HCT of the Whole blood
- Where Transfuse to HCT is always greater than Current HCT

PRBC Units = PRBC in cc divided by 300.
- Where 300 = average volume in one unit of whole Blood
- The usual 250-300 ml unit of red blood cells (PRBCs) has a hematocrit of 55-80%, with some platelets and/or white cells removed during processing.

Total Loss Calculations
- Hypothetical needs based on necessary amount of blood products needed to maintain a patient at a specific HCT
- Transfusion must be guided by patient needs/safety, operative demands/evolution, & current/verified lab results – all to treat and or prevent alterations in O2 delivery and the issues that arise.
- PRBC in cc
  - EBV x ((Desired maintenance HCT)/70)
    - where Desired maintenance HCT = minimum HCT you want to maintain in an active loss situation
    - 70 is the average HCT concentration of PRBC
  - In ACTc Type in Your Desired HCT and then Type in “0” in the Current HCT
- PRBC in units
  - (EBV x ((Desired maintenance HCT)/70))/300
- Where 300 is the average volume of a unit of PRBC
- Whole blood uses the same calculations but the maximum HCT is limited to the maximum HCT available in the WB – where the average is 35%

Figure 18 Transfusion

Coagulation and Resuscitation

It is vital to understand the processes of possible coagulation issues that can arise with large transfusions (6-10 units of PRBCs) in combination with the duration of hypotension or hypoperfusion[5]. Hence, ACTc has provided some general guides and information about the calculations for Platelets, FFP, and Cryoprecipitate.

Platelets[5, 32, 51]
- Rarely indicated for Platelet counts greater than 100 x 10⁹/L
- Usually indicated for levels less than 50 x 10⁹/L

Figure 19 Resuscitation Screen
Can be indicated regardless of normal count values in the presence of known platelet dysfunction and microvascular bleeding.

Dosed at One unit per 10 kg of body weight to see an increase 40 - 50 k

**FFP[5, 32]**
- Used in reversal of warfarin therapy
- Correction of known coagulation deficiencies - in presence of increased (>1.5) PT or PTT or an INR >1.6 (if in active loss and normal starting values - represent > 30% loss of circulating factors) or an INR >1.6
- Used in correction of microvascular bleeding in presence of increased (>1.5) PT or PTT or an INR >1.6
- For correction of microvascular bleeding secondary to coagulation factor deficiency in patients transfused with more than one blood volume and when PT and PTT cannot be obtained in a timely fashion
- Massive blood transfusions – rarely and only when factors V and VIII are less than 25% of normal and increased (>1.5) PT or PTT or an INR >1.6
- Dosed to achieve a minimum of 10% increase in plasma factor concentration
  - 10 – 15 cc/kg
  - One CC/kg increases factors by 1%
  - 5 – 8 cc/kg for coumadin reversal
- Contradicted for augmentation of plasma volume or albumin concentration
- Also used in cases of ATIII deficiencies in which heparinization is need for coronary pulmonary bypass

**Cryoprecipitate[52]**
- Contains concentrated factor VIII, XIII, von Willebrand, fibrinogen, and fibronectin
- Indicated in
  - Hypofibrinogenemia - < 100 mg/dl
  - von Willebrand disease
  - Hemophilia A – when factor VIII is not available
- Dose
  - One unit per 7 – 10 kg
  - will increase fibrinogen 60 -70 mg/dl

Furthermore, ACTc has provided coagulation issue tables where the use of the Coagulation deficiencies and DIC tables granted by Elsevier publication.

**Inhalational Screen**

“Anesthetic solubility is a prime determinant of recovery from anesthesia” – Eger EI II
Apart from TIVA (total intravenous anesthesia) techniques, general anesthesia is maintained via the use of inhalational agents. Detailed knowledge regarding the pharmacokinetics/dynamics is vital for every practitioner to properly administer these agents. [28, 53-60]

- MAC values listed for adults 30 – 55 years of age (40 average) at 1 atm.

**Understanding AGE Adjustments in MAC requirements.**

In understanding the nuances of MAC, ACTc assists in showing the clinician the calculated range of the effects of age on the MAC continuum – from MACawake, MAC, and MACBAR. Based on age calculations of Nickalls, Mapleson [58, 61], Eger’s temperature variations [56, 62-65], and Eger’s and Baileys Context Sensitive Decrement Time Considerations[53, 66-69]. It is also worth noting that Age adjustments are considerations, and not definitive in determining proper intra-operative end tidal concentrations. Each patient presents differently - Age plays a significant part but in no way does it completely describe or define an absolute intraoperative end tidal level.

The MAC continuum shows the implications of specific ET concentrations and the physiologic effects – specifically amnesia, movement, and blocking of adrenergic responses. Using current published research, ACTc interactively shows the effects of increasing age on the continuum. Additionally, the clinician can also see the effects of decreasing temperature on MAC requirements. The inhalation screens show these interactions instantaneously to enforce fundamental MAC teaching. Addition to age adjustments but the addition of MAC multiples can also be seen.
1. Select your agent
2. Determine the decrement desired
3. Select the duration of the anesthetic

Relative times are shown to reach that decrement

– Please see the research constraints below

The addition of the Context Sensitive Decrement Times – utilizes the principles of solubility and time in circuit described by Eger and Bailey[53, 66, 67]. An excellent and complete resource for uptake and distribution is GASMAN software (http://www.gasmanweb.com/). ACTc helps educate the practitioner in comparing various agents and selected duration of the anesthetic vs. the amount of decrement desired. This action alone helps the user understand some important aspects of inhalation elimination. ACTc highly recommends recreating Eger’s research using GASMAN software to completely appreciate CSDTs[66, 70] ACTc is only reporting data found within a constrained research situation to educate the differences between the agents.

**Common Terms**

- At the lower end of the MAC continuum, MACAwake: the average concentration permitting voluntary response to commands
  - Memory is usually lost at this point
  - MACAwake is approximately 0.34 MAC for Desflurane, Isoflurane, and Sevoflurane[56, 71]
  - MACAwake for N20 and Halothane it is 0.5[56]
  - MACAwake /MAC ratio is maintained with advancing age[56]
  - 0.1 MAC is the point where cognition is affected (slight)[54]
  - In reviewing the literature, BIS monitoring has helped validate this point.
    - In a study by Wong[72], where intraoperative ET% of isoflurane (in combination with Fentanyl) was adjusted to BIS values of 50 -60, the average ET% was .39 +/- .05 with no evidence of recall
    - If adjusted for age of the participants, the MAC Awake ET value for isoflurane is .33% (if used in combination with Fentanyl)
    - Furthermore, In a study of fast tracking with Desflurane vs Propofol using BIS, Song provided the following data
      - ET% of Desflurane of 2.7% (with N20 at 65% & Fentanyl)[73]
      - If adjusted for age of the participants, MAC awake in this study = 2.43%
    - Worbel looked at Desflurane concentrations below 1 MAC and found similar results
      - Where BIS 64-50 corresponded to 2.9 +/-1.3 % when used with remifentanil[74]
In reference to the definition that memory is lost at this point, the available BIS studies help validate this very important point.

- **MAC**: Minimum Alveolar Concentration of an anesthetic that produces immobility in 50% of patients exposed to a painful stimuli
- **MAC<sub>bar</sub>**: the anesthetic concentration that blocks autonomic/ adrenergic response to incision
  - Usually resides at the higher end of the MAC Continuum
  - Since MAC<sub>Awake</sub> /MAC ratio is maintained with age, the author also applies Eger’s assumption to the MAC<sub>bar</sub> /MAC ratio.
- **MAC<sub>40</sub>**: The MAC values at age 40 as expressed by Mapleson Age Adjusted calculation (resulted from meta-analysis of available MAC data)[61]
  - Halothane: 0.75%
  - Isoflurane: 1.17%
  - Enflurane: 1.63%
  - Sevoflurane: 1.8%
  - Desflurane: 6.6%
  - N2O: 104%
- **Context-sensitive decrement time (CSDT)**.
  - CSDT are directly influenced by anesthetic duration and individual gas solubility; and expressed as time to reach x% reduction once an anesthetic gas is discontinued
  - Example
    - A 50% decrement time is the time required to obtain a 50% reduction in the ET%
  - Important in considering agent selection and operative management
  - Using CSDT can help a clinician plan on emergence times (using 80% CSDT)
    - If starting point upon cessation of inhalational agent is @ 1 MAC or below
    - Targeting MAC<sub>Awake</sub> at emergence in reference to 80% CSDT has assisted the author in wakeups
    - Useful since the general goal is responsiveness for extubation
    - If cases under 120 minutes, most agents allow the level to obtained in a short period of time[66]
      - The authors data shows @ < 12 minutes
      - This does not include Halothane or Enflurane
    - 95% CSDT is significant for it possibly represent complete clinical recovery.[66]
CSDT are influenced significantly by: percentage of desire reduction, duration of inhalational exposure, and solubility of the inhalational agent.

- Generally, the impact of low solubility is greatest (faster elimination) in higher decrement times (>90%) in cases longer then 60 – 90 minutes.
- The major differences in the rates at which desflurane, sevoflurane, isoflurane, and enfurane are eliminated occur in the final 20% of the elimination process.[53]
- Higher required CSDT (greater then 90%) is dependent on gas solubility
  - The lower the solubility the shorter the time required to obtain a specific CSDT

Studies by Both Eger and Bailey show that regardless of duration show little difference in 50% decrement times for all agents[53, 66]

- Bailey used mathematical calculations vs. Eger’s use of Gas Man software
- Eger and Bailey differ in some points of their findings
  - Bailey indicates that at 60 minutes the 80% decrement times for Sevoflurane and Desflurane are similar; while Enflurane and Isoflurane start diverging significantly – reflecting those agents solubility
  - Eger states that for Isoflurane, Sevoflurane, and Desflurane, the 80% decrement time would be clinically indistinguishable up to 90 – 120 minutes.
  - For the difference of divergence between Sevoflurane and Desflurane for a 90% decrement time
    - Eger indicates this occurs at 120 min
    - Bailey indicates this occurs at 90 min

**Gasshead’s findings on CSDT**

Understanding CSDTs is central in understanding inhalational elimination

- Using the study by Eger as a guide for methodology[66], the author obtained the following data (*note – all references as described below reference the Eger’s primary article unless otherwise stated)
  - Using Gas Man v3.1.6[70]
  - Accepting default lambda values and volumes for all gases and compartments
    - Desflurane 0.42, Sevoflurane 0.65, Isoflurane 1.3, Nitrous Oxide 0.46, Enflurane 1.9, Halothane 2.5
- 70 kg, Open circuit, FGF 10 L/m, VA 4L/m, CO 6 L/m
- Noted CSDT at 50%, 80%, 90% CSDT for all agents at 30 minutes, 1 hour, 90 minutes, 2 Hour, 3 Hour, 4 Hour, 6 Hour, and 12 hours.
- 95% CSDT for only Isoflurane, Sevoflurane, Desflurane, & Nitrous Oxide at 15 minutes, 30 minutes, 1 – 4 hours, 6 hours, & 12 Hours
- 80%, 90%, and 95% were chosen due to clinical experience of decreases required at emergence for extubation.
- Time ranges selected were based on the broad range of case times.

### 50% CSDT

![Graph showing time ranges for 50% CSDT](image)

#### Figure 20 50% CSDT

- The 50% CDST was < 5 minutes for all agents except Halothane, regardless of duration
- This is in line with the findings for both Eger and Bailey
In terms of the 80% CSDT, Bailey indicated that after 45 – 60 minutes both Isoflurane and Enflurane started diverging from Desflurane and Sevoflurane trend line.

Eger indicated that for the 80% CSDT:
- Is short for desflurane, isoflurane, and sevoflurane, particularly for anesthesia in the range of up to 120 min duration.
  - In the authors' data above, this does not apply to higher solubility agents (Enflurane & Halothane)
  - For these agents, anesthetic durations beyond 60 minutes show considerable CSDT.
- The above findings agrees with Eger’s findings that “For anesthesia shorter than 90 min, the times to an 80% decrement would likely be clinically indistinguishable among the three drugs.”
- Eger also states, “For anesthesia longer than 90 min, accumulation of isoflurane in tissue increasingly delays the time to an 80% decrement. These delays might be clinically appreciable.”
  - This does impact on cases where the clinician doesn’t anticipate the time required for emergence
    - At 3 Hours, the time for Isoflurane to reach the 80% CSDT is @ 16 minutes vs 5 minutes for Sevoflurane and 3 minutes for Desflurane
  - Eger further states that “accumulation of drug in tissue does not appreciably influence 80% decrement times for anesthesia of less than 240 min duration” between Sevoflurane and Desflurane.
    - The results above do not reveal this.
- At 12 hours, the lowest soluble agents times are: 3 – 4 minutes for N20 and Desflurane, 8 minutes for sevoflurane, and 47 minutes for Isoflurane
- Main points
  - Duration and solubility have the greatest effect on CSDT
  - Important for planning for emergence, but complete recovery as represented by CSDT>90% have more impact on discharge criteria as shown below for the 90 and 95% CSDT

90 & 95% CSDT

![Figure 22 90% CSDT](image-url)
General Notes

Contraindications

Finally, Inhalation anesthesia is contraindicated in patients with hypersensitivity to halogenated anesthetics & with known or genetic susceptibility to malignant hyperthermia, & severe hypotension.

Nitrous Oxide

[28, 71, 75-77]:

- MAC: 104 ET %
- MAC Awake: 0.55
- Blood Gas Partition Coefficient : 0.47
- 50% decrement time: possibly < 5minutes
  - S/S abate within 5 minutes[78]
  - Author assigned related to solubility resembling Desflurane but lacking potency
- 80% Decrement Time: 9 minutes[69]
  - It is important to note that Context-sensitive Decrement times do not take into account what fraction of MAC a patient is starting at prior to the
cessation of inspired agent. Hence the impact of MAC additives, readiness for emergence, or end points of recovery are not taken into account.

- Most commonly used anesthetic gas
- Symptoms occur in a dose-related fashion with increases in visual analog scale ratings of "anxious", "stimulated", "coasting (spaced out)", "lightheaded", "confused", and "high"[78]
- Only inorganic anesthetic gas
- Anesthetic effects can occur when mixed at 80% with 20% O2
  - Potential for hypoxia if O2 inappropriately mixed OR if high concentration is maintained and abruptly discontinued without increasing delivered O2 concentration to 100% for 5 – 10 minutes (resulting in Diffusional Hypoxia.)
- Due to it’s potentially high inspired concentration it provides a concentration gradient effect and hence affects the increase of the rate of rise in a second gas (Concentration effect and Second gas effect) occurring both on induction and elimination.
- Due to stimulation of catecholamines vs. its depression of myocardial contractility – little change in hemodynamics occur.
  - Unless catecholamine depletion is present
- Diffusion to closed spaces d/t high inspired concentration – resulting in potentially detrimental side effects
  - For example, caution should be used in cases of bowel obstructions, pneumothorax, air embolism, middle ear procedures, uses with sulfur hexafluoride (retinal tears repairs), & pneumocephalus.

**Isoflurane**

[28, 53, 57, 66, 69, 71, 79-83]

- MAC Awake: 0.25 - 0.38
- MAC 1.15 ET %
- MACbar: 1.3
- Blood Gas Partition Coefficient = 1.4
- 50% decrement time: < 5 – 8 minutes (w/o significant change with increased duration of anesthesia)
- 65% decrement time: 5 – 8 minutes (op. durations of 30 – 360 minutes)[53]
- 80% Decrement Time: 17 minutes (for cases < 60 minutes) or up to < 20 - 30 minutes for case great then 60 – 120 minutes[53, 66]; a plateau of 30 minutes occurs @ 200 – 250 minutes and greater[53]
- For decrements >80% - significant time is required for reduction[53, 66]
  - Example: . case with ET ISO at 1.0
  - Need 17 minutes in order to reach ET ISO of 0.2 (80% decrement)
Eger and Shafer indicate that in cases less than 90 minutes, there would be little clinical differences between Isoflurane vs. Sevoflurane vs. Desflurane to obtain a 80% decrement. 90% decrement can require up to 60 minutes. It is important to note that context-sensitive decrement times do not take into account what fraction of MAC a patient is starting at prior to the cessation of inspired agent. Hence the impact of MAC additives, readiness for emergence, or end points of recovery are not taken into account.

- Pungent – limiting its use for inhalational inductions
- Though known to dilate coronary arteries, there is conflicting data showing potential coronary steal can occur with increase heart rates or decreases in pressure
- Bronchodilates
- Decreases SVR with reflective increases in heart rate, yet causes little myocardial depression
- Non-convulsant
- Increases cerebral blood flow and ICP
- Decreases cerebral metabolic requirements
- Due to it’s blood gas partition coefficient, surgical duration greater than 60 minutes can result in 30 minutes to obtain an 80% Context-sensitive Decrement time

Sevoflurane

[28, 66, 71, 76, 83-87]

- MAC Awake: 0.34
- MAC : 2.0 ET %
- MACbar: 2.2 - 3.5
- Blood Gas Partition Coefficient = .63 - .69
- 50% decrement time: < 5 – 8 minutes (w/o significant change with increased duration of anesthesia)
- 65% decrement time: 4 – 7 (op. durations 30 – 360 minutes)
- 80% decrement time: 5  minutes (duration no effect)
- 90% decrement time : < 10 minutes if duration is less then 90 min[53]
  - Due to low blood gas coefficient, context sensitive decrement times similar to Desflurane
  - It is important to note that context-sensitive decrement times do not take into account what fraction of MAC a patient is starting at prior to the cessation of inspired agent. Hence the impact of MAC additives, readiness for emergence, or end points of recovery are not taken into account.
• Nonpungent – easily tolerated for inhalational inductions
• Bronchodilates
• Compound A exposure in patients also has been shown to rise with increased Sevoflurane concentrations and duration of anesthesia.
  o Compound A end product increases significantly with prolonged dehydration of Baralyme. Hence, Sevoflurane degradation to Compound A is decreased by lowering the concentration of monovalent bases in the carbon dioxide absorbent
  o Renal effects of low-flow sevoflurane are similar to those of isoflurane in patients with stable renal insufficiency.
• Dose related cardiac depressant without increase in heart rates less than 2 MAC
• Increases cerebral blood flow and ICP
• Decreases cerebral metabolic requirements

Desflurane
[28, 53, 57, 66, 71, 83]
• MAC Awake: 0.34
• MAC : 6.0% ET
• MACbar: 1.3
• Blood Gas Partition Coefficient = .42
• 50% decrement time: < 5 – 8 minutes (w/o significant change with increased duration of anesthesia)
• 65% decrement time: 3 minutes (op. durations of 30 – 360 minutes)
• 80% decrement time: 5 minutes
• 90% decrement time: < 10 minutes[53]
  o It is important to note that context-sensitive decrement times do not take into account what fraction of MAC a patient is starting at prior to the cessation of inspired agent. Hence the impact of MAC additives, readiness for emergence, or end points of recovery are not taken into account.
• Rapid increases in concentration is associated with tachycardia and hypertension
• Pungent – limiting its use for inhalational inductions
• Increases cerebral blood flow and ICP
• Decreases cerebral metabolic requirements

Enflurane
[28, 53, 69, 82, 88]
• MAC Awake: 0.27
• MAC : 1.7% ET
• MAC_{bar}: 1.6
• Blood Gas Partition Coefficient = 1.9
• 50% decrement time: < 5 minutes (w/o significant change with increased duration of anesthesia)
• 80% Decrement Time: 35 minutes (for cases > 60 minutes)
  o It is important to note that context-sensitive decrement times do not take into account what fraction of MAC a patient is starting at prior to the cessation of inspired agent. Hence the impact of MAC additives, readiness for emergence, or end points of recovery are not taken into account.
• For decrements > 80% - significant time is required for reduction[53, 66]
• Has a mild sweet odor
• Myocardial depressant and decreases SVR
• Seizures have been seen with high concentrations and hypocapnia
• Avoid in patients with preexisting renal dysfunction d/t fluoride byproduct

Halothane
[1, 28, 71, 88]

• MAC : 0.75 ET %
• MAC Awake: 0.55
• MAC_{bar}: 1.45
• Blood Gas Partition Coefficient = 2.4
• Dose dependent myocardial depressant
• Dilates coronary arteries
• Decreases myocardial oxygen demands
• Blunts baroreceptors in aortic arch – decreasing vagal stimulation
• Bronchodilates
• Pungent
• Increases cerebral blood flow and ICP
• Hepatitis occurs in 1: 35,000
  o At risk are Exposure to multiple halothane anesthetics in a short period, Obese and middle age women, and familial history to halothane toxicity.

Factors Affecting MAC

• Age[56, 58, 61]
  o > 1 year of age – MAC requirements are reduced @ 6% per decade of life
- Age adjusted MAC values can be obtained by using the following calculation by Mapleson:
  - \( \text{MAC}_{\text{age}} = \text{MAC}_{40} \times 10^{-0.00269 \times (\text{Age}-40)} \)
  - Using the above formula,
    - the specific change per decade is 5.422% which is close to Eger’s quote of 6%
- Furthermore one can also obtain MAC Multiples by the following:
  - \( \text{MAC Multiple} = \text{MAC}_{\text{age}} \times 10^{-0.00269 \times (\text{Age}-40)} \)
- If N20 is used – the following calculation can be used to find the total MAC value
  - \( \left( \frac{\text{Fraction of Expired Agent}_{\text{agent}}}{\text{MAC}_{\text{age/agent}}} \right) + \left( \frac{\text{Fraction of Expired Agent}_{N20}}{\text{MAC}_{\text{age/N20}}} \right) \)
- **Temperature**[56, 62-65]
  - MAC requirements decrease 4 – 5% per centigrade
  - <20 degrees centigrade – no anesthesia is required
  - Calculated 1- (.05)(37-t)
    - Where t = core temperature
  - N20 is not affected by Temperature changes
- **Pregnancy**[89, 90]
  - MAC requirement decrease by 30%
- **Other factors:**
  - Alpha 2 agonists
  - Lidocaine
  - \( \text{Pa02} < 38\text{mmHG} \)
  - \( \text{BP} < 40 \text{mmHg} \)
  - Preoperative medications
  - ETOH
**ACTc Application of MAC**

The inhalational screen condenses the aforementioned research data onto easily navigated screens.

1. All Inhalational agents are represented by the drop down list

   a. Age input box along with temperature adjustment

   a. Age calculations are as follows

   Age adjusted MAC calculations are as follows with inputted age applied within calculation from Mapleson

   - \( MAC_{age} = MAC_{40} \times 10^{-0.00269} \text{ (Age-40)} \)

   Hence \( MAC_{age} = \)

   - If Isoflurane is selected then
     - \( 1.17 \times 10^{-0.00269} \text{ (Age-40)} \)
     - If Sevoflurane is selected then
     - \( 1.8 \times 10^{-0.00269} \text{ (Age-40)} \)
     - If Desflurane is selected then
     - \( 6.6 \times 10^{-0.00269} \text{ (Age-40)} \)
     - If Halothane is selected then
Where \( X = 0.75 \times 10^{-0.00269 (Age-40)} \)

- If Enflurane is selected then
  \( 1.68 \times 10^{-0.00269 (Age-40)} \)

- If N2O is selected then
  a. \( 104 \times 10^{-0.00269 (Age-40)} \)

Temperature adjustment Calculation uses Eger temperature adjustment and then utilizes the Mapleson age calculation

b. Works only for temp below 37
c. Calculation
  o \( Z = 1 - 0.05(37-t) \)
d. Applied to Age Adjustment
  o \( Z \times MAC_{age} = MAC_{40} \times 10^{-0.00269 (Age-40)} \)

The screen will show the following:

- **MAC awake value from data & ET calculation** = MAC Awake * Age Adj. MAC % (see above for equation)
- **MAC BAR** = MAC BAR * Age Adj. MAC %
- **50% and 80% Decrement** values from data

**AGE MAC CAL**

The AGE MAC CAL screen allows the user to see the impact of age on ET requirements with the use of nitrous as the secondary gas.

Based on research from

1. First: User inputs values in all top three boxes and
   a. MAY NOT input an age LESS than 1
   b. May only enter a value of ET N20 between 0 – 70%
2. User will then select an Agent from the following list:
   a. Isoflurane
   b. Sevoflurane
   c. Desflurane
   d. Halothane
   e. Enflurane

On this screen, Current MAC is then calculated by the following formula

1. **If Isoflurane is selected then**
   - Current MAC = (ET Agent/X) + (ET N20/Y)
   - Where X = 1.17 * 10^(-0.00269 (Age-40))
   - Where Y = 104 * 10^(-0.00269 (Age-40))

2. **If Sevoflurane is selected then**
   - Current MAC = (ET Agent/X) + (ET N20/Y)
   - Where X = 1.8 * 10^(-0.00269 (Age-40))
   - Where Y = 104 * 10^(-0.00269 (Age-40))

3. **If Desflurane is selected then**
   - Current MAC = (ET Agent/X) + (ET N20/Y)
   - Where X = 6.6 * 10^(-0.00269 (Age-40))
   - Where Y = 104 * 10^(-0.00269 (Age-40))

4. **If Halothane is selected then**
   - Current MAC = (ET Agent/X) + (ET N20/Y)
   - Where X = .75 * 10^(-0.00269 (Age-40))
5. If Enflurane is selected then
   - Where $Y = 104 \times 10^{-0.00269} \text{ (Age-40)}$

AGE ET CAL

- This screen allows the user to input a desired MAC level along with the optional use of nitrous – the difference with the above screen is that the user already knows the ET reading of his primary anesthetic gas

1. If Isoflurane is selected then
   - $AGENT \ ET\% \ should = \ (\text{Desired Combined MAC Level} - Z) \times X$
   - Where $Z = \text{Desired ET N2O/Y}$
   - Where $Y = 104 \times 10^{-0.00269} \text{ (Age-40)}$
   - Where $X = 1.17 \times 10^{-0.00269} \text{ (Age-40)}$

2. If Sevoflurane is selected then
   - $AGENT \ ET\% \ should = \ (\text{Desired Combined MAC Level} - Z) \times X$
   - Where $Z = \text{Desired ET N2O/Y}$
   - Where $Y = 104 \times 10^{-0.00269} \text{ (Age-40)}$
   - Where $X = 1.8 \times 10^{-0.00269} \text{ (Age-40)}$

3. If Desflurane is selected then
   - $AGENT \ ET\% \ should = \ (\text{Desired Combined MAC Level} - Z) \times X$
   - Where $Z = \text{Desired ET N2O/Y}$
   - Where $Y = 104 \times 10^{-0.00269} \text{ (Age-40)}$
   - Where $X = 6.6 \times 10^{-0.00269} \text{ (Age-40)}$

4. If Halothane is selected then
   - $AGENT \ ET\% \ should = \ (\text{Desired Combined MAC Level} - Z) \times X$
   - Where $Z = \text{Desired ET N2O/Y}$
   - Where $Y = 104 \times 10^{-0.00269} \text{ (Age-40)}$
   - Where $X = .75 \times 10^{-0.00269} \text{ (Age-40)}$

5. If Enflurane is selected then
   - $AGENT \ ET\% \ should = \ (\text{Desired Combined MAC Level} - Z) \times X$
   - Where $Z = \text{Desired ET N2O/Y}$
Where \( Y = 104 \times 10^{-0.00269 (\text{Age-40})} \)
Where \( X = 1.68 \times 10^{-0.00269 (\text{Age-40})} \)

3D Anatomical Figures

- Using clinical and educational expertise, the author generated the anatomical figures used in Anesthesia Clinical Tutor and Calculator. Produced using a combination of the following programs below and these references[1, 2, 91-95]:
  - **Poser**\(^{\text{TM}}\) by Curious Labs v 6.0
    - efrontier
    - 5615 Scotts Valley Drive
    - Suite 210
    - Scotts Valley, CA 95066, USA
    - [http://www.e-frontier.com](http://www.e-frontier.com)
  - **Adobe Photoshop CS2**\(^{\text{TM}}\)
    - Adobe Systems Incorporated
    - 345 Park Avenue
    - San Jose, CA 95110-2704 USA
    - [www.adobe.com](http://www.adobe.com)
  - **Jasc Paint Shop Pro v 9.1**\(^{\text{TM}}\)
    - Corel Minneapolis
    - 7905 Fuller Road
    - Eden Prairie, MN 55344 USA
    - [http://www.corel.com](http://www.corel.com)

Spinal

ACTc provides visual cues on dosing guides for both spinal and epidural cases.

Dosing suggestions were derived from product inserts then cross referenced with anesthesia textbooks, research, and references.[1, 2, 92, 93, 96-102]

Understanding of pharmacodynamics /kinetics, anatomical, proper technique (s), readiness for emergencies, patient selection, and equipment requirements is critical for any safe and successful spinal anesthetic. Complete and detailed appreciation is required prior to any patient care. Additionally, direct communication with the surgeon for case specific need(s) and duration will assist each clinician in determination of the appropriate regional anesthetic agent.
Factors Affecting SAB[103, 104]

- Baricity – affecting spread post-injection
  - Patient positioning after injection, esp. for hypobaric and hyperbaric solutions
    - Hypobaric - rising
    - Hyperbaric – descending
    - Isobaric – little or minimal spread
- Increase intrabdominal pressure will diminish dose requirements
  - Pregnancy
  - Ascities
  - Tumors
- Age
- Additives
  - Epinephrine
  - Opiates
  - Clonidine
- Height/Weight
  - Chandrasekhar suggestion was “Doses are based on a 66 - inch [167.64 cm] patient. An additional 2 mg tetracaine, 10 mg of lidocaine, or 1.5 mg bupivicaine should be added or subtracted for each 6 inches [15.24 cm] in height above or below 66 inches” [104] (conversions - authors addition)
- Gender
- Site of Injection
- Direct of bevel at time of injection
- Diffusion
- Characteristics of the spinal fluid
- Amount and Volume of the anesthetic

Below is a general guide using drug inserts cross referenced with several published anesthesia resources (see below for details).

Published dosing recommendations for spinal anesthetics – unless indicated all doses are for hyperbaric solutions in adult patients. An interesting note, many drug inserts defer to “standard textbooks” for more detailed dosing.

**Tetracaine:**

Drug manufacture (Taylor Pharmaceuticals & Abbott) recommending using 1% solution for:
- Perineum: 5 mg (0.5 cc + 0.5 cc spinal fluid) – injected at 4th lumbar interspace
o Perineum & lower extremities: 10 mg (1 cc + 1 cc spinal fluid) - injected at 3rd or 4th lumbar interspace.
o Costal Margins (T5-T7)*: 15 mg (1.5 to 2 cc + 1.5 – 2 cc spinal fluid) – injected at the 2nd, 3rd, or 4th lumbar interspace.
o These recommendations fall midline with Tezlaff Suggestions (shown below) and corresponds with what the author has experienced clinically.
o Duration is noted between 2 – 3 hours
o Maximum spinal dose: 20 mg

[76, 98, 105]
*author’s interpretation

**Bupivacaine:**

Drug manufacture (Hospira) recommends using 0.75%
o 7.5 mg or 1.0 mL lower extremity and perineal procedures including TURP and vaginal hysterectomy. Twelve mg (12 mg or 1.6 mL) has been used for lower abdominal procedures such as abdominal hysterectomy, tubal ligation, and appendectomy.
o No recommendations are listed for levels higher level procedures. [106]
o These recommendations are listed in the table below with a recommendation for blocks up to T6 (which the author has used and agrees with the recommended dose)
o Duration of sensory blockade (time to return of complete sensation in the operative site or regression of two dermatomes) following a 12 mg dose averages 2 hours with or without 0.2 mg epinephrine.
o 12 mg Spinal averages 3 1/2 hours without epinephrine and 4½ hours with the addition of 0.2 mg epinephrine.
o In comparison with to equal milligram doses of hyperbaric Tetracaine, the duration of sensory blockade was the same but the time to complete motor recovery was significantly longer for Tetracaine.
o The addition of 0.2 mg epinephrine significantly prolongs the motor blockade and time to first postoperative narcotic.
o Maximum Doses
  o Maximum single dose 225 mg with Epinephrine (1:200K) – maybe repeated once every 3 hours
  o Maximum single dose spinal dose 175 without Epinephrine - maybe repeated once every 3 hours
  o Maximum spinal dose 20 mg [76, 98, 106]

**Lidocaine 5% in 7.5 Glucose**
Previously, widely used in the United States - recently concerns over the post-operative occurrences of transient neurologic syndrome (TNS) have made this anesthetic fall out of general favor for SAB. The 5% solution had been withdrawn from the market during 2003.

Drug manufacture (Hospira) recommends using 5% Lidocaine Hydrochloride and 7.5% Dextrose Injection
  o The dosage recommended for normal vaginal delivery is approximately 1 mL (50 mg).
  o For Caesarean section and those deliveries requiring intrauterine manipulations, 1.5 mL (75 mg) is usually adequate.
  o Surgical anesthesia:
    o The dosage recommended for abdominal anesthesia is 1.5 to 2 mL (75 to 100 mg). No specific dose for dermatomal level. Hospira recommends that standard textbooks should be consulted for specific techniques and precautions for various spinal anesthetic procedures.
    o Duration for a 50 mg dose is @ 100 min. – with an additionally 40 minutes if an analgesic is added
    o Duration for doses between 75 – 100 mg is @ 120 min.
  o Maximum Doses
    o Spinal dose: 100 mg
    o Maximum individual dose 7 mg/kg with Epinephrine
    o Maximum individual dose 4.5 mg/kg without Epinephrine[76, 98, 107]

**Procain 10%**

Standard textbooks should be consulted for specific techniques and precautions for various spinal anesthetic procedures.

Drug manufacture (Hospira) recommends using 10% Procaine
  o For Perineum: 50 mg (0.5 cc + 0.5 cc of dilutent) – if injected at the 4th Lumbar Interspace
  o Perineum lower extremities: 100 mg (1.0 cc + 1.0 cc of dilutent) – if injected at the 3rd or 4th Lumbar Interspace
  o Up to Costal Margins (T5 – T7)* 200 mg (2.0 cc + 1 cc of dilutent) – if injected at the 3rd or 4th Lumbar Interspace
  o Maximum spinal dose: 1000 mg
[76, 96, 108]
*author’s interpretation
**Ropivacaine**

The author contacted AstraZeneca (1/2/2007) for US prescribing information – currently Ropivicaine is not approved for Intrathecal use in the United States nor does the package insert provide and direction for spinal anesthetic use.

Numerous studies have been done, but no formal recognition has been received as of the present. AstraZeneca does provide dosing information on their website ([http://www.anesthesia-az.com/article/509875.aspx](http://www.anesthesia-az.com/article/509875.aspx)) under the banner “Global prescribing information,” of which spinal doses can be found.

General Intrathecal dosing recommendations from AstraZeneca
- Using 5.0 mg/ml using, a volume of 3 – 4 cc.
  - = 15 – 20 mg
  - Onset occurs within 1 – 5 minutes
  - Duration of 2 – 6 hours[109]

### Spinal Doses

<table>
<thead>
<tr>
<th>Medication</th>
<th>T10</th>
<th>T8</th>
<th>T6</th>
<th>Duration Plain</th>
<th>Duration with Epinephrine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetracaine 1%</td>
<td>4 - 7.5 mg</td>
<td>8 - 12 mg</td>
<td>10 - 16 mg</td>
<td>1.5 - 2 hrs</td>
<td>2 - 4 hrs</td>
</tr>
<tr>
<td>Bupivacaine 0.75%</td>
<td>4 - 10 mg</td>
<td>12 mg</td>
<td>14 - 18 mg</td>
<td>1.5 - 2 hrs</td>
<td>2 hrs</td>
</tr>
<tr>
<td>Lidocaine 5% in 7.5 Glucose (Caution w/ TNS)</td>
<td>50 mg</td>
<td>60 - 70 mg</td>
<td>70 - 100 mg</td>
<td>1 hr</td>
<td>1 - 1.5 hrs</td>
</tr>
<tr>
<td>Procaine 10%</td>
<td>75 mg</td>
<td>125 mg</td>
<td>200 mg</td>
<td>45 min</td>
<td>1 hr</td>
</tr>
<tr>
<td>Ropivicaine 0.5% *</td>
<td>8 - 12 mg</td>
<td>13 - 16 mg</td>
<td>16 - 18 mg</td>
<td>1.5 - 2 hrs</td>
<td>1.5 - 2 hrs</td>
</tr>
</tbody>
</table>

[98, 100, 104]  
*Check for FDA approval – not approved for SAB in U.S.

### Spinal Opiates

Dosing suggestions were derived from product inserts then cross referenced with anesthesia textbooks, research, and references. [28, 76, 102, 104]

Use of Intrathecal opiates injected, as an adjunct to intraoperative anesthesia techniques and to mitigate postoperative pain.

Understanding of pharmacodynamics /kinetics, anatomical, proper technique (s), readiness for emergencies, patient selection, and equipment requirements is critical for any safe and successful anesthetic. Complete and detailed appreciation is required prior to any patient care. Additionally, direct communication with the surgeon for case specific
need(s) and duration will assist each clinician in determination of the appropriate regional anesthetic agent.

**Fentanyl**  
Dose: 5 – 25 mcg  
Onset 5 – 10 min  
Duration 2 – 4 hours  
If respiratory depress occurs, it can occur earlier (< 6 hours) vs later

**Sufentanil**  
Dose: 2 – 10 mcg  
Onset 5 – 10 min  
Duration 2 – 4 hours  
If respiratory depress occurs, it can occur earlier (< 6 hours) vs later

**Morphine**  
Dose:  
- 0.1 – 0.3 mg  
- 0.5 – 1 mg  
Onset 30 – 60 min  
Duration 6 – 24 hours  
If respiratory depress occurs, it can occur earlier (< 6 hours) and later >6hr [93]

**Meperidine**  
Dose: 10 – 20 mg

**Epidural**

ACTc provides epidural segment calculations with desired level considerations. Review the number of levels desired prior to inputting any other values.

Understanding of pharmacodynamics /kinetics, anatomical, proper technique(s), readiness for emergencies, patient selection, and equipment requirements is critical for any safe and successful spinal anesthetic. Complete and detailed appreciation is required prior to any patient care.
Additionally, direct communication with the surgeon for case specific need(s) and duration will assist each clinician in determination of the appropriate regional anesthetic agent.

Accessed via similar techniques as a spinal but has an added benefit of placement of an indwelling catheter. Hence, the ability of continuous access to the epidural space, allows anesthesia providers another route to provide perioperative and postoperative pain control.

**Determination of Dose and Spread**

Dosing suggestions were derived from product inserts then cross referenced with anesthesia textbooks, research, and references [99, 101, 104, 110, 111]

- **Volume**
  - Generally 1.6 cc of anesthetic per segment to be block is required.

- **Age**
  - Multiple studies have found a spread of dose requirements based on age and segments blocked
    - Ranging from 0.25% - 1% per year reduction per year after 20 years of age[101, 110, 111]
  - Generally, a 50% reduction in dose is required in the elderly and neonate
  - Using Bromage suggestion is the most conservative at 1% per year reduction on dose

- **Pregnancy**
  - A 30% reduction in dose is required

- **Vasoconstrictors**
  - Epinephrine 5 mcg/ml or 1:200 K, will generally increase the duration of the block

- **pH**
  - Adding 1 mEq of NaHCO3 to each 10 cc of local anesthetic produces a faster onset, spread, and completeness of block

**Redosing** [193, 23]

Redosing for epidural anesthetics allows for proper planning for prolongation of block if required. Identical agent concentration of initial bolus for a surgical block is assumed in the following 2 segment regression.
<table>
<thead>
<tr>
<th>Medication</th>
<th>Time to 2 segment regression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choroprocaine</td>
<td>45 – 70 min</td>
</tr>
<tr>
<td>Prilocaine</td>
<td>90 – 130 min</td>
</tr>
<tr>
<td>Lidocaine</td>
<td>60 – 150 min</td>
</tr>
<tr>
<td>Mepivacaine</td>
<td>60 – 160 min</td>
</tr>
<tr>
<td>Etidocaine</td>
<td>120 – 240 min</td>
</tr>
<tr>
<td>Bupivacaine</td>
<td>120 – 260 min</td>
</tr>
</tbody>
</table>

**Chloroprocaine**

Drug manufacture (Bedford Labs) recommends 2 to 2.5 mL per segment of a 2% or 3% solution can be used.

- The usual total volume of chloroprocaine hydrochloride injection is from 15 to 25 mL.
- Repeated doses 2 to 6 mL less than the original dose may be given at 40 to 50 minute intervals.
- The maximum single recommended doses of chloroprocaine in adults are:
  - Without epinephrine, 11 mg/kg, not to exceed a maximum total dose of 800 mg
  - With epinephrine (1:200,000), 14 mg/kg, not to exceed a maximum total dose of 1000 mg.
- Fast Onset: 10 – 15 minutes
- Duration: 30 min. – 1 hour (Plain), 60 – 90 Min (with epinephrine)[76, 98, 99, 112]

**Lidocaine**

- Drug manufacture (Hospira) recommends using 1% - 2% Lidocaine Hydrochloride solutions
- 2–3 mL of the indicated concentration per dermatome
- In Normal Healthy Adults Maximum Doses
  - With epinephrine should not exceed 7 mg/kg (3.5 mg/lb) of body weight and in general it is recommended that the maximum total dose not exceed 500 mg.
  - When used without epinephrine, the maximum individual dose should not exceed 4.5 mg/kg (2 mg/lb) of body weight and in general it is recommended that the maximum total dose does not exceed 300 mg.
  - For continuous epidural or caudal anesthesia, the maximum recommended dosage should not be administered at intervals of less than 90 minutes.
• Onset 15 min
• Duration
  - 80 – 120 min (plain)
  - 120 – 180 min (with epinephrine)[76, 98, 99, 113]

**Bupivacaine**

- Drug manufacture (Hospira) statements for epidural:
  - 0.25% — incomplete motor block.
    - “For operations in which muscle relaxation is not important, or when another means of providing muscle relaxation is used”
    - “Onset may be slower than with the 0.5% or 0.75%.”
  - 0.5% — Provides motor blockade but muscle relaxation may be inadequate for operations in which complete relaxation is required
  - 0.75% — Produces complete motor block.
    - Most useful for epidural block in procedures requiring complete muscle relaxation.
    - Not for obstetrical anesthesia.
- In Normal Healthy Adults Maximum Doses
  - “Maximum dosage limit must be individualized in each case after evaluating the size and physical status of the patient, as well as the usual rate of systemic absorption from a particular injection site.”
  - Up to 225 mg with epinephrine 1:200,000
  - Up to 175 mg without epinephrine.
  - 24 hour dose should not exceed 400 mg. [114]
- Onset: 10 – 20 Min
- Duration: 180 – 300 min (with epinephrine)[98, 99]

**Etidocaine**

- Not FDA approved for pregnancy, labor, delivery or lactation. Local anesthetics rapidly cross the placenta and when used for epidural, paracervical, pudendal or caudal block anesthesia, can cause varying degrees of maternal, fetal, and neonatal toxicity.
- For Epidural use 1% and 1.5%, concentrations are recommended
- Maximum single does
  - 300 mg without Epinephrine
  - 400 mg with Epinephrine
- Usual volume 15 – 30 cc
- Onset 5 – 15 min
- Duration 2 – 4 hours[98, 99]
Mepivacaine

- Drug manufacture (Hospira) recommends that standard textbooks should be consulted to determine the accepted procedures and techniques for the administration.

- For Epidural use 1%, 1.5%, and 2% concentrations are recommended

- Dosing
  - The recommended single adult dose for un-sedated, healthy, normal-sized individuals should not usually exceed 400 mg.
    - This should be reduced in elderly or debilitated patients.
  - Maximum doses of 7 mg/kg (550 mg) + epinephrine
    - Not recommended, except in exceptional circumstances
    - Cannot be repeated at intervals of less than 1 1/2 hours.
    - The total dose for any 24-hour period should not exceed 1,000 mg

- Onset: Fast – 5 – 15 min
- Duration: 1 – 3 hours[97-99, 115]

Ropivacaine

- Epidural infusions can be used up to 24 hours
- Surgical concentrations: 0.5%, 0.75%, 1%
- C-Section & Thoracic Epidural concentration: 0.5% & 0.75%
- Labor: 2% concentration

- Duration
  - 0.5% : 2 – 4 hours
  - 0.75%: 3 – 5 hours
  - 1% - 4 – 6 hours
  - 2% (labor) : 0.5 – 1.5 hour

- Onset
  - 0.5% : 15 – 30 min
  - 0.75%: 10 – 20 min
  - 1%: 10 – 20 min
  - 2% (labor) : 10 – 15 min[76, 109]

Prilocaine

- Metabolism leads to formation of methaemoglobin
  - More than 600 mg prilocaine is needed to cause a clinically apparent methaemoglobinemia in the normal adult
• Concentrations: 1 – 3%
• Dosing
  • The recommended single adult dose for un-sedated, healthy, normal-sized individuals should not usually exceed 600 mg.
• Onset: Fast – 5 – 15 min
• Duration: 1 – 3 hr [98, 99]

**Epidural Opiates**

<table>
<thead>
<tr>
<th>Name</th>
<th>Dose</th>
<th>Onset</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfentanil</td>
<td>15 mcg/kg</td>
<td>15 min</td>
<td>1 - 2 hr</td>
</tr>
<tr>
<td>Fentanyl</td>
<td>25 - 150 mcg</td>
<td>5 - 10 min</td>
<td>4 - 6 hr</td>
</tr>
<tr>
<td>Hydromorphone</td>
<td>0.75 - 1.5 mg</td>
<td>5 - 10 min</td>
<td>3 - 18 hr</td>
</tr>
<tr>
<td>Meperidine</td>
<td>12.5 - 100 mg</td>
<td>5 - 30 min</td>
<td>4 - 20 hr</td>
</tr>
<tr>
<td>Methadone</td>
<td>1 - 5 mg</td>
<td>10 - 15 min</td>
<td>3 - 11 hr</td>
</tr>
<tr>
<td>PF Morphine</td>
<td>1 - 5 mg</td>
<td>30 - 60 min</td>
<td>12 - 24 hr</td>
</tr>
<tr>
<td>Sufentanil</td>
<td>10 - 50 mcg</td>
<td>5 - 15 min</td>
<td>4 - 7 hr</td>
</tr>
</tbody>
</table>

Opiates used in conjunction with local anesthetics can reduce intraoperative and postoperative pain requirements. Selection of individual agents are determined by perioperative and postoperative pain needs.

  - Side effects[102, 116]
    - Puritis (1 – 100%), 15 – 18%, Nausea Vomiting (20 – 50%), Urinary retention (15 – 25%), Respiratory Depression (0.1 – 2%)

**Drug Screen**

The medication dosages complied in the drug section were obtained first from the package insert, then cross referenced using multiple current pharmacology and anesthesiology text books.[1, 2, 5, 7, 76, 93, 120-123]

Highlighting any drug will bring up its Name, dose and concentration up for review. Clicking “GO” will bring the
user to the modifying screen where the user can change, modify, add notes, or delete their drug data.


The following drug inserts were also referred to for direction:

<table>
<thead>
<tr>
<th>Company</th>
<th>Drug</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abbott</td>
<td>Halothane</td>
</tr>
<tr>
<td>Abbott</td>
<td>Isoflurane</td>
</tr>
<tr>
<td>Abbott</td>
<td>METOCURINE IV</td>
</tr>
<tr>
<td>Abbott</td>
<td>Remifentanil</td>
</tr>
<tr>
<td>Abbott</td>
<td>Sevoflurane</td>
</tr>
<tr>
<td>AHA</td>
<td>Aspirin PO ACLS</td>
</tr>
<tr>
<td>AHA</td>
<td>Captopril PO ACLS</td>
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60
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<td>Ondasetron IV</td>
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<td>Alfentanil</td>
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<td>Aminophylline</td>
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<td>Milrinone</td>
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<td>MSO4 IV, IM</td>
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<td>Hospira</td>
<td>Nalbuphine IV, IM</td>
</tr>
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<td>Hospira</td>
<td>Nitroprusside</td>
</tr>
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<td>ICN Pharmaceuticals, Inc.</td>
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<td>Monarch Pharmaceuticals</td>
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<td>ROCURONIUM IV</td>
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<td>Organon</td>
<td>SUCCINYLCHOLINE IV</td>
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<td>Amiodarone</td>
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<tr>
<td>Xanodyne</td>
<td>Amicar</td>
</tr>
</tbody>
</table>
Pharmaceuticals

| Xanodyne Pharmaceuticals | Methadone IV |

The Propofol + Ketamine drip included in the program is a commonly used combination in our practice – refer to your institutional guidelines prior to use.

Furthermore, the drip range for Vasopressin is provided by research currently in multiple trauma & shock states. [124-128]

Dose ranges publish varies:

- From 0.04 units/min[128]
- To 0.00002 units/kg/min up to 0.0003 U/kg/min[127]
- And 0.067 IU/min[126]

**Malignant Hyperthermia Screen**

Information obtained [129, 130] & reprint permission provided by: MALIGNANT HYPERTHERMIA ASSOCIATION of the United States (MHAUS), 11 East State St. PO Box 1069 Sherburne, NY 13460

- MH Hotline: 1-800- MH-HYPER (1-800-644-9737) or 1-315-464-7079 if outside the U.S.
- [http://www.mhreg.org/](http://www.mhreg.org/)

AND

Malignant Hyperthermia Investigation Unit
ES11-423, Toronto General Hospital
200 Elizabeth St.
Toronto, ON  M5G 2C4
416-340-3128 (Phone)
416-340-4960 (FAX)
**Dose calculations**

1. Calculate dose from calculated KG using 2 -3 mg per kg
   - Example: If the Patient is 100 kg, then 200 mg – 300 mg is shown in the box
2. Calculate “Volume” by dividing the above range by .33
   - This is due to if reconstituted as per directions 60 cc per vial – there is only .33 mg per cc.
   - Example: If the dose range is 200 mg – 300 mg, then
     - 200 / .33 = 606 cc
     - 300 / .33 = 909 cc
     - SO “606 – 909 cc” is shown in the box
3. Calculate “Number of Vials” by dividing Volume range by 60
   - Example: If the dose range is 606 cc – 909 cc, then
     - 606 / 60 = 10.1
     - 909 / .33 = 15.15
     - SO “10.1 – 15.15 ” is shown in the box

**Vital statistics**

These tables are viewable when pediatric patients are selected, accessed on the “Patient Data” screen by clicking on “VS”

Adult Values[131]

<table>
<thead>
<tr>
<th>Normal Range of Resting Values</th>
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</thead>
<tbody>
<tr>
<td><strong>Variable</strong></td>
</tr>
<tr>
<td>Resp. Rate / min</td>
</tr>
<tr>
<td>TV (cc/kg)</td>
</tr>
<tr>
<td>HR / min</td>
</tr>
<tr>
<td>Syst.</td>
</tr>
<tr>
<td>Diast.</td>
</tr>
</tbody>
</table>

- Systolic and Diastolic range from 5th to 95th Height percentile
- 50th percentile BP values (representing normal ranges) are shown
- Normal Range of Resting Values for RR/min, and HR /min are shown
- Alternative lowest blood pressure: 70 = 2*age[131, 132]
Male BP

<table>
<thead>
<tr>
<th>Variable</th>
<th>NB</th>
<th>1 yo</th>
<th>3 yo</th>
<th>5 yo</th>
<th>10 yo</th>
<th>12 yo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resp. Rate / min</td>
<td>30 - 60</td>
<td>22 - 30</td>
<td>22 - 30</td>
<td>20 - 24</td>
<td>16 - 22</td>
<td>16 - 22</td>
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<tr>
<td>TV (cc/kg)</td>
<td>10 - 12</td>
<td>10 - 12</td>
<td>10 - 12</td>
<td>10 - 12</td>
<td>10 - 12</td>
<td>10 - 12</td>
</tr>
<tr>
<td>HR / min</td>
<td>100 - 160</td>
<td>90 - 150</td>
<td>80 - 125</td>
<td>70 - 115</td>
<td>70 - 110</td>
<td>60 - 100</td>
</tr>
<tr>
<td>Syst.</td>
<td>60 - 96</td>
<td>80 - 89</td>
<td>86 - 95</td>
<td>90 - 98</td>
<td>97 - 106</td>
<td>101 - 110</td>
</tr>
<tr>
<td>Diast.</td>
<td>30 - 62</td>
<td>34 - 39</td>
<td>44 - 48</td>
<td>50 - 55</td>
<td>58 - 63</td>
<td>59 - 64</td>
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</tbody>
</table>

Female BP

<table>
<thead>
<tr>
<th>Variable</th>
<th>NB</th>
<th>1 yo</th>
<th>3 yo</th>
<th>5 yo</th>
<th>10 yo</th>
<th>12 yo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resp. Rate</td>
<td>30 - 60</td>
<td>22 - 30</td>
<td>22 - 30</td>
<td>20 - 24</td>
<td>16 - 22</td>
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<tr>
<td>TV (cc/kg)</td>
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<td>10 - 12</td>
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<td>80 - 125</td>
<td>70 - 115</td>
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</tr>
<tr>
<td>Syst.</td>
<td>60 - 96</td>
<td>83 - 90</td>
<td>86 - 93</td>
<td>89 - 96</td>
<td>98 - 105</td>
<td>102 - 109</td>
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<tr>
<td>Diast.</td>
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<td>38 - 42</td>
<td>50 - 54</td>
<td>52 - 56</td>
<td>59 - 62</td>
<td>61 - 64</td>
</tr>
</tbody>
</table>

**Pediatric outpatient considerations:**

Pediatric Patients at risk:
- Low hemoglobin or hematocrit
- A history of respiratory distress syndrome
- Aspiration
- Prematurity
- History of apnea or with feeding is also at risk.
- Ex-premature should not be operated on as an outpatient until they are at least 46 weeks postconceptual age (gestational age plus postnatal age).
- The ex-premature less than 46 weeks postconceptual age must be apnea monitored for 24 hours postoperatively as an inpatient.[133]
  - Patients with a history of prematurity can potentially develop significant periods of apnea in the postoperative period. There are multiple studies that address this issue, all of which are a topic of great controversy. Ages ranging 44 weeks post–conceptual age (PCA: gestational age at birth + chronological age) to 60 weeks PCA (to potentially achieve < 1% incidence) at cited for guidelines as admittance guidelines for overnight monitoring for apnea.[10, 134-136]
Many facilities choose cutoff between 46 and 60 weeks postconceptual ages.

Regardless of age, if patient continues to have apnea at home, inpatient overnight monitored is required.

**Laboratory Values**

Various references were used to build the base of the lab values in ACTc.[137-139] Each lab value can be modified/changed to each users preferences.

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
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</thead>
<tbody>
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<td>Alk Phos</td>
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<td>ALT</td>
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<td>Ammonia</td>
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<tr>
<td>Amylase</td>
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<td>Anion Gap</td>
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<tr>
<td>Arterial Blood Gas Base Excess</td>
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<td>Arterial Blood Gas HCO3</td>
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<td>Arterial Blood Gas O2 Sats</td>
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<td>Arterial Blood Gas PO2 (@21%)</td>
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<td>Arterial Blood Gas PCO2</td>
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<td>Arterial Blood Gas pH</td>
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<td>Antithrombin III</td>
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<td>Bilirubin (Direct)</td>
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<td>Bilirubin (Indirect)</td>
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<td>Bilirubin (Total)</td>
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<td>Bleeding Time (BT)</td>
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<td>BUN</td>
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<td>Calcium (CA)</td>
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<td>Cardiac Enzymes: Creatine Phosphokinase</td>
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<td>Cardiac Enzymes: MB fraction</td>
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<td>Cardiac Enzymes: Troponins T and I</td>
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<td>Cardiac Enzymes: Troponin</td>
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<td>Chloride (CL)</td>
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<td>PTT</td>
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</tr>
</tbody>
</table>
**PH/ETCO2/K calculator**

Using the following general premise that Changes in ETCO2 will affect blood pH hence can impact serum potassium:

- **Respiratory Driven pH Changes:**
  - Acute Acidosis/Alkalosis: pH change = 0.008 units per 1 mm Hg Paco2 change
  - Chronic Acidosis: pH change = 0.003 units per 1 mm Hg Paco2 change
  - Chronic Alkalosis: pH change = 0.0017 units per 1 mm Hg Paco2 change [140]
  - The equation means that a change of 0.1 in the pH can be caused by either:
    - A respiratory change (PCO2 change) of 12mmHg – 12.5 (10 mmHg change in PCO2 = 0.8 change in pH), or[140, 141]
    - A metabolic change (Base Excess change) of 6 mEq/L.
    - A mixture of the two.[141]

- **Potassium**
  - In evaluating serum potassium, the consideration must include the possible acute changes in serum pH.
  - Having an inverse relationship
    - When serum pH falls, serum potassium rises because potassium shifts from the cellular to the vascular space.
    - Conversely, when serum pH rises, serum potassium falls because potassium shifts intracellularly.[142]
  - For any pH change the effect of acidaemia is greater than alkalaemia.
- In general, serum K⁺ decreases by approximately 0.3 mEq/L – 0.6 mEq/L for every 0.1 U increase in pH above normal. [142, 143]
- During hyperventilation for each 0.1 pH unit, the serum K⁺ will decrease rapidly by about 0.2 mmol/L[144]
- There are conflicting studies
  - Acute respiratory acidosis does not affect plasma potassium concentration. [145, 146]
  - Another study showed Respiratory and metabolic alkalosis and respiratory acidosis result in similar small shift of potassium into and out of cell respectively (0.1-0.4 mmol/l on average). [143]
- Non-organic results in a shift of 0.24-1.7 mmol/l per 0.1 unit pH change.
- In chronic acid-base disorders, the final potassium levels are affected primarily on renal function and to lesser degree to transcellular shifting. [143]

The actual tool is shown below where the user input the initial values and selecting the pathologic state, the possible outcomes will be then calculated.

![Figure 24 PH Calculator Input Screen](image)

Calculated values:

![Figure 25 PH Calculated values](image)
Settings Screen

ACTc settings section allows for modification of all listed databases within ACTc

- “New” starts a new input dialog to add to your database
  - Ensure you are in the correct category
- “Edit” allows for modifying the highlighted entry
- “Delete allows for complete removal of the item form you database

![Settings Screen](image-url)
Trouble Shooting and Questions

Q. My credit card has been declined.

A. We are sorry for this inconvenience. Credit Card Users outside the US, may have Your Credit card declined.

We do have an alternative method using PAYPAL.

Send $69.99 to the following to Gasshead’s Paypal ID:

buyactc@gasshead.com

Once we have received notification of your purchase - a link and code will be forwarded to you for your Full Version

Q: On a PALM installation, I do not see the ACTc icon only the GASSHEAD icon.

A: Not all files have been install on the device or you have installed it onto a storage card. Ensure that you have selected all the uncompressed installation files and drag them to the HotSync Icon or your PALMOOne quick install tool.

-If you are using a MAC, please uncompress the files to your desktop and install the files (not the folder) to your palm device.

-Also if you have Epocrates installed - you "might" have to uninstall Epocrates first then install ACTc, then you may reinstall Epocrates.

- Finally, if you do not have enough storage on the device, ACTc will not install.

Again, DO NOT install on a storage card.

Q: I did not receive an email confirmation of my purchase
A: Please adjust your junk mail settings and goto our Login Page where you can view your information and resend your information to your email in question

Click here to GOTO the Login PAGE

**Q: (PPC) When changing some screens, sometimes I have a portion of a previous screen still present or see portions of graphics. Or Program exits unexpectedly.**

A: ACTc requires a current processor with spare RAM available. Hence, stopping all unrequired programs will allow ACTc to function correctly.

Please close all running programs and re-attempt using ACTc. For PPC users: GOTO Settings>Systems>Memory>Running Programs>Select (Highlight the program(s) and click "Stop"

**Q: How can I see my account information?**

A: Sign in to your account using your email provided at time of purchase and your password you made. If you have forgotten your password, enter your password in the “Forgot Password” page and it will be sent to you.

**Q: The program will not install all the files (PALM)**

A: Please check to ensure you have adequate memory on the device to install ACTc. Additionally, issues have been identified with the drug program Epocrates, where Epocrates will prevent ACTc from installing. Severe cases have required a full un-installation of Epocrates then an installation of ACTc, then a re-installation of Epocrates.

**Q: How do I see more of the cell in the Snap-Shot and Drug Screen?**

A: Click on the Right Edge of the cell with your stylus and hold and drag open the cell
Q: I have a Palm Device and cannot read all the words in the drug detail box or lab detail Box

A: Use your toggle button (the large round or square button on the front of your PALM device) – click on the right side of the button to read more text

Q. (PPC) I have a prior installation of ACTc and have errors after install version 3.0. What should I do?

A:

6. Please uninstall both versions
7. Click on Programs
8. Click on File Explorer
9. Click on My Documents
10. A drop down list will appear
11. Click on My Device
12. Click on Program files
13. Delete any ACTc folders or Gasshead folders

If you still have a ACTc icon in the program list (usually occurs with Windows mobile 2003 – if you have Windows mobile 2002 see the next Q & A for deleting details)

1. Connect your PDA to ActiveSync and allow it device to synchronize
2. In the Microsoft ActiveSync box
3. Click on File
4. Click on Explore
5. In the new Window that appears, Double click on “My Windows Mobile-Based Device”

6. Click on Windows

7. Click on Start Up

8. Click on Programs

9. Click on ACTc and delete

10. Reinstall ACTc version 3

Q: I have the old ACTc icon in my program list – How can I get rid of it (usually seen in Windows Mobile 2003)?

A:

1. Connect your PDA to ActiveSync and allow it device to synchronize

2. In the Microsoft ActiveSync box

3. Click on File

4. Click on Explore

5. In the new Window that appears, Double click on “My Windows Mobile-Based Device”

6. Click on Windows

7. Click on Start Menu

8. Click on Programs
9. Click on ACTc and delete

**Q: I have the old ACTc icon in my program list – How can I get rid of it (usually seen in Windows Mobile 2002)?**

**A:**

1. Connect your PDA to ActiveSync and allow it device to synchronize

2. In the Microsoft ActiveSync box

3. Click on File

4. Click on Explore

5. In the new Window that appears, Double click on “My Windows Mobile-Based Device”

6. Click on Windows

7. Click on Start Menu

8. Click on ACTc and delete

**Q: I noticed that all your Help screens indicate specific references in your Readings Section, is there a main document that this originated or is there a help document available?**

**A:** All sections of ACTc have been well researched and reviewed, all supporting documents have been listed and full credit has been given to all researchers, software, development team members, pharmaceuticals, publication permission sources, and educators. You are reading the document.

**Q: What if I change my PDA how do I re-register?**

**A:** The device key is unique to each device and the unlock codes only work for that device with that unique code. Gasshead recognizes that PDAs are upgraded (usually once every 3 – 5 years), and offers one free transfer to a new device in that time period. Please email support for guidance at: support@gasshead.com
Readings and References

ACTc readings and Calculations allow the user to review or modify all anesthesia calculations and review the references and readings list


84. Abbott Laboratories, Ultane (sevoflurane) - drug insert. 2005: North Chicago, IL 60064, USA.

129. Malignant_Hyperthermia_Investigation_Unit, MALIGNANT HYPERTHERMIA. 2000: Toronto, ON M5G 2C4

130. MHAUS, MALIGNANT HYPERTHERMIA. 2000: Sherburne, NY.


