IJPP is a quarterly subscription journal of the Indian Academy of Pediatrics committed to presenting practical pediatric issues and management updates in a simple and clear manner.

Indexed in Excerpta Medica, CABI Publishing.

Vol.10 No.1
Jan.-Mar. 2008

Dr. K. Nedunchelian
Editor-in-Chief

Dr. S. Thangavelu
Executive Editor

CONTENTS

FROM THE EDITOR’S DESK 3

TOPIC OF INTEREST - EQUIPMENT UPDATE

Common bedside equipments 6
- Thangavelu S

Neonatal central lines 15
- Srinivas Murki

Monitoring equipments in pediatric intensive care units 21
- Anil Sachdev, Vikas Bansal

Preliminary medical accessories 30
- Sunil Srinivasan

Drug delivery devices 39
- Ramachandran B, Ravikumar KG

Pulmonary devices in office practice 44
- Nagabhushana S

Life support equipments 51
- Anand Shandilya, Surpreet Nagi

Journal Office and address for communications: Dr. K. Nedunchelian, Editor-in-Chief, Indian Journal of Practical Pediatrics, 1A, Block II, Krsna Apartments, 50, Halls Road, Egmore, Chennai - 600 008. Tamil Nadu, India. Tel. No.: 044-28190032 E.mail: ijpp_iap@rediffmail.com
FOR YOUR KIND ATTENTION

* The views expressed by the authors do not necessarily reflect those of the sponsor or publisher. Although every care has been taken to ensure technical accuracy, no responsibility is accepted for errors or omissions.

* The claims of the manufacturers and efficacy of the products advertised in the journal are the responsibility of the advertiser. The journal does not own any responsibility for the guarantee of the products advertised.

* Part or whole of the material published in this issue may be reproduced with the note "Acknowledgement" to "Indian Journal of Practical Pediatrics" without prior permission.

- Editorial Board
We from the Journal Committee and Editorial Board of Indian Journal of Practical Pediatrics (IJPP), congratulate Dr. A. Balachandran for successfully completing six years as Editor-in-Chief, IJPP. With IJPP completing fifteen years, we would like to fondly recall the efforts put in by our previous editors, Dr. A. Parthasarathy, Dr. B. R. Nammalwar and Dr. M. Vijayakumar with their respective teams, who nurtured the journal to the present level. We assure you that we will keep up the momentum set by our predecessors to take the journal to further heights in future.

According to the “World Health Organization” (WHO), basic services to support the human health are chemistry, physics and informatics. Chemistry is the basis of pharmacy, while physics is the basis of “Medical Instruments and Equipments” (MIE). The diagnosis and therapy of diseases rely much on informatics. As physicians, while we concentrate on gaining knowledge in diagnosis and therapy, we do not concentrate much on “Medical instruments and Equipments”. Even if we want to get information on MIE, there is usually a lack of instantaneous, comprehensive answer from a reliable source and we have to depend on the product manual entirely. On most of the occasions this may not give correct information, for obvious reasons.

When we plan to buy instruments and equipments, there are many aspects which are to be considered. One should be sure enough that it would certainly add to improvement in the management and not be one more addition to the equipment pool. After having decided to procure one, we should think carefully what options we need in the equipment, whether it should be a basic model or more advanced one with multiple options and whether it would meet the requirement at present or in future.

To be confident about all these aspects, it is pertinent to have good knowledge about the basics of functioning and operation of equipment, problems anticipated and the ways and means of rectifying them, etc. While choosing an equipment, issues like the track record of its manufacturing company, cost benefit analysis when many companies manufacture the same equipment, availability of spare parts and consumables, service particulars, etc have to be looked in to always.

Once procured, the equipment should be put into optimum use. To obtain the maximum benefit from the equipment, it should be maintained properly and standardised periodically. Anticipation, identification and rectification of errors in time would be ideal for the effective functioning of the equipment.

With these things in mind our team selected “Equipment Update” as topic of interest for this issue highlighting the afore mentioned hitherto unattended areas. The topics were selected in such a way to cover preliminary medical equipments needed in an office practice as well as in neonatal nursery and in a PICU setup. The information on these equipments should be known to every physician, as they are useful in day to day practice and we hope that all the readers will benefit immensely from the topics covered.

Dr. K. Nedunchelian,  
Editor-in-Chief.
GENERAL

Print the manuscript on one side of standard size A4, white bond paper, with margins of at least 2.5 cm (1”) in double space typescript on each side. Use American English using Times New Roman font 12 size.
Submit four complete sets of the manuscript.
They are considered for publication on the understanding that they are contributed to this journal solely.
All pages are numbered at the top of the right corner, beginning with the title page.
All manuscripts should be sent to: The Editor-in-Chief, Indian Journal of Practical Pediatrics

MANUSCRIPT

1st Page –
Title
Name of the author and affiliation
Institution
Address for correspondence (Email, Phone, Fax if any)
Word count
No. of figures (colour / black and white)
No. of references
Authors contribution

2nd Page –
Abstract (unstructured, not exceeding 100 words) with key words (not exceeding 4)

3rd Page -
Acknowledgement
Points to remember (not more than 5 points)
Text
References
Tables
Figures – should be good quality, 4 copies black & white / colour, (4 x 6 inches – Maxi size) Glossy print. (Each colour image will be charged Rs.1,000/- separately)
Legends

TEXT

Only generic names should be used
Measurements must be in metric units with System International (SI) Equivalents given in parentheses.

REFERENCES

Recent and relevant references only
Strictly adhere to Vancouver style
Should be identified in the text by Arabic numerals in parentheses.
Type double-space on separate sheets and number consecutively as they appear in the text.
Defective references will entail rejection of article

TABLES

Numbered with Roman numerals and typed on separate sheets.
Title should be centered above the table and explanatory notes below the table.

FIGURES AND LEGENDS

Unmounted and with figure number, first author’s name and top location indicated on the back of each figure.
Legends typed double-space on separate sheet. No title on figure.
Article Categories

*Review article*
Article should be informative covering the recent and practical aspects in that field. Main articles can be in 1500 – 2000 words with 12 – 15 recent references and abstract not exceeding 100 words.

*Case report* (covering practical importance)
250 – 600 words, 8 – 10 recent references

*Clinical spotters section*
100 – 150 words write up
With 1 or 2 images of clinically recognizable condition
(of which one could be in the form of clinical photograph / specimen photograph / investigation)

*Letters to the Editor*
200 – 250 words pertaining to the articles published in the journal or practical viewpoints with scientific backing and appropriate references in Vancouver style.

*Selection procedures*
All articles including invited articles will be peer reviewed by two masked reviewers. The decision of the Editorial Board based on the reviewers’ comments is final.

*Check List*
Covering letter by corresponding author
Declaration (as enclosed) signed by all authors **
Manuscript (4 copies)
Accompanied by a copy in CD / or submit as an email attachment in addition to hard copy.

Failing to comply with the requirement at the time of submission would lead to the rejection of the article.

*Author’s contribution / Authorship Criteria*
All persons designated as authors should qualify for the authorship. Authorship credit should be based on substantial contributions to i) concept and design, or collection of data and interpretation of data; ii) drafting the article or revising it critically for important intellectual content; and iii) final approval of the version to be published. All conditions i), ii) and iii) must be met.

**Declaration by authors**
I/We certify that the manuscript titled ‘……………………………….’ represents valid work and that neither this manuscript nor one with substantially similar content under my/our authorship has been published or is being considered for publication elsewhere. The author(s) undersigned hereby transfer(s), assign(s), or otherwise convey(s) all copyright ownership, including any and all rights incidental thereto, exclusively to the Indian Journal of Practical Pediatrics, in the event that such work is published in Indian Journal of Practical Pediatrics. I / we assume full responsibility for any infringement of copyright or plagiarism.

Authors’ name(s) in order of appearance in the manuscript

Signatures (date)

All manuscripts, which are rejected will not be returned to author. Those submitting articles should therefore ensure that they retain at least one copy and the illustrations, if any.
COMMON BEDSIDE EQUIPMENTS

* Thangavelu S

Abstract: Point of care testing (POCT) enables the clinician to do important tests at bedside, community or at home setting, either invasively or noninvasively. It needs training for the practitioner or paramedics or the caretaker at home to perform these tests. POCT has revolutionized the management in critical care setting and is now advancing towards monitoring critically ill patients in community, in view of availability of portable and simple devices. The cost is the initial concern and is expected to come down with time and increased utilization. Rapid collection of information will aid the clinical management in a great way. Future will be on POCT along with appropriate coordination, help and supervision by the main laboratory. Main lab and POCT are not contradictory to each other but are mutually enriching.

Key words: Point of Care Testing, Glucometer, Cold light source, Bilirubinometer, Urine Strips.

Laboratory has become a third eye for a physician. It aids his clinical acumen in taking right and quick decisions. But having a laboratory attached is expensive and cumbersome for a practicing clinician. Point of care testing (POCT) enables the clinician to use some common bedside equipments for rapid diagnosis and expeditious clinical management.

In this article common bedside equipments like glucometer, cold light source, bilirubinometer and urine diagnostic strips are described. Except cold light source, all the others are relatively economical.

GLUCOMETER

In the 1940s, Dr. Free developed the first self-testing kits allowing diabetics to monitor their blood sugar by checking their urine at home. Early indicators for home analysis were based on urine testing. First dextrostix was marketed by Ames in 1964. Since then their utility has been massively increasing worldwide. But only 0.1 % of total diabetic population in India use glucose monitoring devices compared to 33 % in US. In the last few years this percentage is on the increase in our country.

What is glucometer?

Glucometer is a portable blood glucose monitor which checks the level of blood glucose from less than a drop of blood obtained from a finger prick or an alternate site.

Who needs it?

Any physician’s office, hospital with emergency rooms, intensive care units and for self monitoring of glucose at home by patients.

Goals of using the glucometer

a) Keep track of glucose levels over time at home, b) To help making day-to-day decisions for managing blood glucose, c) Recognize emergency situations like hypoglycemia.

* Asst. Professor of Pediatrics,
Intensive Medical Care Unit,
Institute of Child Health and Hospital for Children
Chennai. India.
How do they work?

1. Reflectance photometers: Plastic test strip is impregnated with chemicals which react with glucose in the drop of blood. In the first generation glucometers, hydrogen peroxide is produced in the oxidation reaction between glucose and glucose oxidase. This changes color proportionate to the glucose concentration which is measured photo-metrically.

2. Electrochemical Sensors: In newer generation of glucometers an electrochemical cell is incorporated within the device. This measures the integrated current produced by the glucose oxidation reaction, a quantity that is proportional to the amount of glucose present.

Accuracy

Most of the glucometers of standard manufacturers have small deviation from laboratory reference values (±10-15%). Factors affecting accuracy include calibration of meter, ambient temperature, pressure used to wipe off strip, size of blood sample, high levels of certain drugs in blood, hematocrit, dirt on meter, humidity, and ageing of test strips.

a. Hematocrit: Most of the glucometers are calibrated for 40 –50% hematocrit. In critically ill child the hematocrit may be 30% or less, neonates have hematocrit of 60 – 70% and patients with DKA may have hematocrit of 60% or more. Patients with higher hematocrit will usually test lower blood glucose and those with lower hematocrit will test higher. Some glucometers are calibrated for hematocrit between 20 – 70% and hence the hematocrit level has no effect on glucose.

b. Other factors: Many factors including uric acid, glutathione, vitamin C, lipemia, O₂ therapy, mannitol, xylose, dopamine, aspirin, paracetamol, estrogens, corticosteroids, sodium fluoride and hemolysed sample cause interference. Some environmental factors like high altitude, humidity and temperature can also affect the functioning of the test strips. Hence they should be stored in airtight containers.

Caution while using glucometers

1. Glucometer use for hypoglycemia: An imprecision of ±15% is less of a problem for high glucose levels than low. There is little difference in the management of a glucose of 200 mg/dL compared with 260 mg/dL (i.e., a “true” glucose of 230±15%), but the difference between 70 mg/dL and 55 mg/dL (i.e., 67±15%) raises uncertainty.

2. Glucometers are not recommended for the diagnosis of diabetes but only as a screening tool. Any initial abnormal sugar level by a glucometer should be confirmed by standard lab testing.

3. Potential risks of inaccurate readings when using a glucometer: Both malfunction of the meter as well as human error can lead to inaccuracy. Meter malfunction can be avoided by periodic calibration and by doing quality check by control solutions or electronic controls. Other common causes of inaccurate readings include dirty or wet hands, too small sample size, dirty meter, outdated test strip, damaged meter, low batteries and incorrect technique. When alcohol is used to sterilize the sample site, it must dry completely before blood is drawn or it can affect the reading. Training, certification, documentation, quality assurance and both internal and external quality control will reduce the errors.

Choosing the right glucometer

Choice depends on individual needs and comfort. Factors to be considered, when choosing a glucometer are:

1. Size of the glucometer: Smaller ones are convenient for carrying, but are easier to misplace. Bigger ones are convenient for
handling and inserting and preferred by older patients.

2. Amount of blood needed for each test: The size of the drop of blood needed by different models varies from 0.3 to 10 µl.

3. Cost of the glucometer and testing strips: Most of the basic models cost less than Rs.2000. Consider sale prices, rebate offers etc. Test strips are often more expensive in the long term than the meter itself. Accessories for the glucometer include pricking device, lancets, control solution and strips. So, cost should be calculated including the accessories. Lancing pens cost about Rs. 350. Usual cost of strip will be Rs.20 to Rs.25 and of the lancet Rs.3 to Rs.5.

4. Memory of the glucometer: Internal memory size depends on the amount of data that can be stored in the meter which can range from 100-150 test results.

5. Refill testing strips: Availability of smaller number of strips is advantageous for economical reasons for the buyer. Eg. 10 strips (available with one touch Ultra and Acucheck, Prestige IQ test kit).

6. Alternative site testing other than finger tips: (Available in Prodigy, Ascensia Breeze, Freestyle, OneTouch Ultra, Ultra2) Upper arm, forearm, hand, calf, abdomen and thigh are utilised. These areas are less painful and smaller blood samples are enough. However, blood in the fingertip is quicker to show changes in glucose levels than blood in other parts of the body. Alternative site is not ideal when glucose levels are changing rapidly (e.g. after a meal, taking insulin or during or after exercise) and when the glucose level is low.

7. Testing speed: The time taken to read a test strip may range from 5 to 60 seconds for different models.

8. Specimen type/sampling technique: For home monitoring, a drop from finger prick is enough. Some glucometers use a “hanging drop” of blood versus a small drop for strips that draw blood in with a capillary action (One touch Ultra and Acucheck).

9. Display: a) Larger and easy to read display is preferable. b) The glucose value is displayed in mg/dL or mmol/L. There have been a couple of published instances in which someone with diabetes has been misled into the wrong action by assuming that a reading in mmol/L was really a very low reading in mg/dL, or the converse. So one must carefully read whether it is in mg or mmol. c) In some, the last test result is displayed when meter is turned on.

10. Availability of good service network support system: Some models come with an instructional video and some offer a 24-hour toll-free number for customers who are having problems with their meter.

11. Fancy features: Hypoglycemia alarm, voice meter, weekly average are some of the fancy features available with some of the glucometers.

12. Data management capability: Many meters now have sophisticated data handling capabilities. Data can be downloaded to a computer that has diabetes management software to display the test results. In some meters additional data entry such as insulin dose, food, or exercise is possible. (Eg. Accu-Check Advantage, Accu-check Compact, Freestyle, OneTouch ultra, Ascensia Glucometer Elite XL, Prestige IQ).

13. Battery used: In some situations, regular battery with larger sized meters is preferred than button battery because of easy availability even in smaller towns and for safety for children.
14. Measurement range for most of the common meters: 0-20 to 500-600 mg/dL. Below and above the range, display will show low or high. We should note the upper and lower limits from the individual manufacturers.

15. Price range: Standard meters cost between Rs.500 to Rs.3,000.

16. Convenience of strip: Some strips like Acutrend sensor comfort has small curvature at the side of the strip. This is a comfortable facility than the testing spot in the middle.

17. Calibration: Calibration has to be done at the beginning and whenever it is deviating from the concomitant lab values or periodically once or twice in a year. The amount of chemical on test strips can vary from batch to batch. In order to ensure accuracy, most meters must be calibrated, with every new batch of strips. Calibration is done by entering the testing code in the glucometer, with every batch of strips.

18. Test quality control solutions or electronic controls: Test quality control solutions and electronic controls are both used to check the operation of meter. Test quality control solutions with known glucose values check the accuracy of the meter and test strip.

How to use a glucometer?

1. First, set out the glucometer, a test strip, a lancet and an alcohol prep pad.

2. Wash the hands to prevent infection.

3. Decide where to obtain the blood from, usually a fingerprick or an alternate site which is being permitted by the recent glucometers.

4. Turn on the glucometer and place a test strip in the machine when the machine is ready. Verify the code of the strip and the code on the meter. Watch the indicator for placing the blood to the strip.

5. Make sure the hand is dry and wipe the area selected with an alcohol prep pad and wait until the alcohol evaporates.

6. Pierce finger tip on the soft, fleshy pad and obtain a drop of blood. To minimize discomfort or bruising, it may be of help to use the side of a finger, wash hands in warm water, shake the hands or use finer-tipped lancets.

7. Place the drop of blood on or at the side of the strip.

8. The glucometer will take a few seconds to display the reading.

Tips for maintenance

1. Make sure to keep appropriate batteries and strips in stock.

2. Lancets come in different gauges. Higher the number, finer the lancet. They are of single patient use and should not be exchanged between patients. Dispose off lancets in a puncture-proof container, to prevent needle-stick accidents.

3. Keep the glucometer and test strips in a clean, dry place. The expiry date and code on the strips should be checked every time.

4. Do not drop the meters, or carry to moist places like bathrooms, washbasins etc.

5. Cleaning. Some meters need regular cleaning to be accurate. Clean the meter using a dampened soft cloth with soap and water. Avoid alcohol unless recommended in the instructions.

Latest developments

Samples can be taken from upper arm, thigh, forearm, calf and the hand (alternate sites). Only 0.3 microliters sample is required. Some systems allow patients to apply a second blood drop to the test strip. Some other systems have a built in voice meter with a speaker that gives
results and these are useful for the visually impaired. Unique 10-test cartridge replaces diabetic test strips in some newer glucometers. Cartridge automatically calibrates glucometer. The DEX system can download directly into a personal computer and then be faxed or e-mailed to a health care professional.

**Medisafe:** Blood glucose test tip system is also a new addition, which uses blood glucose tips instead of strip.

**Future development:** Development is aiming at two aspects - measuring glucose without pricking the skin and continuous monitoring.

**Continuous monitoring:** There are new devices to continuously monitor the glucose. But these devices do not replace conventional blood glucose monitoring. (GlucoWatch Biographer, Medtronics, DexCom STS System, MiniMed and Diasensor are the new devices for continuous monitoring).

**COLD LIGHT SOURCE**

This is a special light source without heat radiation, useful in level II and level III neonatal centres.

**Indications**

1. Cold light source can be used to transilluminate the chest to detect pneumothorax. Pneumothorax may be shown as a hyper-illuminating area. Transillumination is far quicker than chest X-ray. If time permits it can be confirmed by X-ray. It can also be useful to detect pneumopericardium and abdominal free air prior to X-ray. 2. Transillumination is used to locate artery in arterial puncture. 3. To locate peripheral vein in securing venous access. Using transillumination, venous access can be established with just one venipuncture in most of the patients. 4. This can be also used for phototherapy where both facilities are available in a brand called BiliBlanket (Fig.1).

**Models**

There are two popular models of cold light source available in the world market.

1. **BiliBlanket:** It provides two features, a transilluminator and high output phototherapy system. Parts include a soft fiberoptic pad, high-intensity lighting, an optional transilluminator, automatic shut-off, hour meter, adjustable light...
output and easily replaceable lamp. Unlike other forms of phototherapy, the baby may be cuddled, cared for and even nursed while receiving treatment. Parent and infant bonding can take place without interruption.

2. Olympic medical Trans-Lite: It is a portable transilluminator. Unlike earlier equipments which were bulky, this is lightweight and portable according to manufacturer. It is found to emit more light and less heat and also supported by rechargeable batteries. Trans-Lite also has an adjustable intensity control. This brand has two models (1) Standard Trans-Lite (red light) 57122 for infants. (2) Hi-Intensity Model (white light) 57124 for older children and adults. The first model has two features, a transilluminator and phototherapy unit which allows the baby to be cuddled without interruption and even nursed while receiving phototherapy. The second which is light weight, emits more light and less heat with adjustable intensity control.

**Procedure for pneumothorax**

Make the room darker for better visualisation of hyperlucent areas. Place the transilluminator along the posterior axillary line on the suspected side. Move up and down along the posterior axillary line and above the nipple. It is better to transilluminate both sides for comparison. Presence of chest wall edema and pulmonary interstitial emphysema may give false results.

**Safety precautions**

These include the use of infrared and ultraviolet blocking filters to prevent excess heat. The 4-foot fiberoptic cable and recessed safety tip on the light cable prevent direct contact of the optical fibers with the infant’s skin.

Cautions: 1. Keep the light source on a non absorbent surface and avoid keeping over carpet or crib mattress.

Potential risks: Despite claims by the manufacturers, burns are a potential risk.

**URINE DIAGNOSTIC STRIPS**

Rapid diagnostic tests like urine strips are very handy for bed side assessment. At the same time they have inherent limitation.

**Situations where they may be useful**

1. In a child with polyuria, glycosuria diagnosed by uristrip in the physician’s office will be very valuable in planning admission and investigation.

2. In a known diabetic patient with fever and vomiting, presence of ketones in the uristrip will warrant hospitalization without any delay.

3. In a child with nephrotic syndrome on treatment coming for review, presence or absence of protein in the uristix will help the physician to decide the need for further tests.

4. For a physician in village or small towns with non availability of lab support urine dipstick for nitrites is useful to decide, if urine culture is needed and antibiotics are to be started.

**Composition:** These reagent strips consist of a plastic strip affixed with reagent papers and calibration pad. This facilitates measurement of urine constituents quickly at bedside for everyday diagnosis at home or hospital.

**Various brands available in the market**

1. Diastix Reagent strip for detecting glucose in the urine.

2. Ketodiastix Reagent strip for detecting glucose and ketone in the urine.

3. Albustix Reagent strip for detecting proteins in the urine.
4. Urine multistix: This provides test for sugar, ketones, leucocytes, protein, nitrites, bilirubin, urobilinogen, specific gravity, blood and pH.

5. URS-K • URS-3 • URS-10

Each vial of urinalysis reagent strips includes a colour coded chart. The reactive colour of each panel on the test strip is compared to the closest corresponding colour on the result chart. The concentration level range for each chemical marker is indicated below each colour block on the result chart based on colour intensity or colour matching.

Various constituents detected

1. Leucocytes: Test reveals the presence of granulocyte esterase and favours infection. When leucocytes are not be detectable by microscopy because of lysis, urine strip will show positive results. Presence of high glucose, high specific gravity and antibiotics like cephalexin can decrease the test positivity. Lymphocytes are not detected by this test. Optimal results are obtained from first morning specimen or from the urine sample passed four hours after last voiding.

2. Nitrites: Positivity of nitrites suggests the presence of $10^5$ or more organisms in the urine. Intensity of colour in the result does not correlate with number of organisms. False negative results can occur when infecting organism does not contain reductase or when urine has not been retained in the bladder long enough (4-8hrs) for reduction of nitrate to occur.

3. Glucose: The test is specific for glucose and does not detect other sugars. Presence of high ketones, cleaning agents will affect the test result.

4. Blood: This test is highly sensitive to blood, but result is altered by many drugs like vitamin C and povidone iodine from the fingers of medical staff.

5. Bilirubin: Presence of even trace amounts requires further investigations.

6. pH: To improve accuracy, use freshly voided urine.

Precautions

1. Dip the strip into the urine. Fluid should be allowed to cover all the reagent areas on the strip. Any excess urine should be wiped off on the edge of the container. Lay the strip flat on a dry surface to prevent urine from the reagent areas mixing together. Observe the changes in the reagent areas in the recommended time. Changes after this time may not have any diagnostic significance. Accurately watch each area and record correctly.

2. Use only clean containers to collect urine, because disinfectants and preservatives will affect the result.

3. Urine specimen should not be exposed to sunlight which will affect the result of bilirubin and urobilinogen.

4. Incorrect result may occur if the strip is shaked within the specimen container. Too short or too long dipping time also leads to error.

5. Large amounts of ascorbic acid in the urine will affect many constituents in the urine.

6. Few other causes of erroneous results are improper storage of strips or touching the strips.

7. Sensitivity is altered by many common factors, hence major decisions on diagnosis or therapy should not be based solely on this test and should be established by other standard tests.

BILIRUBINOMETER

This is a simple bedside equipment to measure total bilirubin, by spectrophotometry, useful mainly in the management of neonatal jaundice.
**Advantages**

1. Measured at bedside and the result is available within 5 minutes.

2. Blood is collected in a capillary tube and volume required is about 100 micro litre (0.1ml) i.e. one or two drops taken from heel prick. There is no need for a venepuncture and hence can be repeated frequently.

3. Doctor or a trained nurse or a technician can use this comfortably.

4. No reagent or recurrent expenses are required except capillary tubes which are available in any local market.

5. No calibration or lab experience is required.

6. With its low cost per test, it is an economical test.

**Disadvantages**

Disadvantage of a bilirubinometer is that it measures only total serum bilirubin. But in neonates the hyperbilirubinemia is mostly indirect and hence it is very useful.

**Equipment kit**

Equipment kit consists of micro centrifuge to spin the blood, lancet for heel prick, capillary tube, wax or clay to seal one end of the capillary tube and bilirubin measuring part of the equipment.

Additional spares should be available in the lab which are - Bulb/LED, fuses of all appropriate amperages, capillary tube holder and calibration standard set. It is preferable to purchase all additional spares at one order, because specific spares for the model may not be available in local market.

**Who needs it?**

Any one (physician or health care provider) who deals with neonatal jaundice, where the lab bilirubin measurement is neither available nor reliable.

**Available brands**

1. Bilifuge

2. The Advanced Model BR2 Bilirubin STAT-Analyzer: The Model BR2 measures total and direct bilirubin from a single 30µL sample. Total bilirubin is determined immediately, and direct bilirubin takes just two minutes on the sample. It is easy to use, with simple setup, calibration, and operation.

3. Neonatal Bilirubinometer Model TOT BIL: Is equipped with a built-in printer for the results. Volume needed is 70 microlitre (0.07ml). Weight of the machine is 2.7 kg and hence portable. It has got a LCD display, a printer and data storing system upto last 1000 results. Measurement range- 85 to 510 mmol or 5 to 30 mg. Calender and timer are also incorporated.

4. Reichert Unistat Bilirubinometer.

**Test procedure**

Collect blood in a heparinised capillary tube. Dip one end of the capillary tube in the clay. Keep it in the centrifuge with covered end at the bottom. Keep another capillary tube in the opposite side for balance. Set the time as per the recommendation. After centrifuging, pull out the cell holder and keep it in the measurement part of the bilirubinometer and the result is available in seconds.

**Points to Remember**

- *Bed side equipments are the domain of every clinician. Hence one should be familiar about all aspects of these equipments including cost, mode of purchase and operation.*
• **Point of care testing (POCT) is a growing field and every physician must update his knowledge and utilise these facilities in patient care. He also plays a greater role in educating paramedics and care takers at home setting.**

• **POCT is a great boon for the community physician and practitioners of smaller hospitals.**

**Acknowledgement**

Sincere thanks to the following colleagues from Chennai for their suggestions and material : Dr. A.Panneerselvam, Diabetologist; Dr. M.Vijayakumar, Nephrologist; Dr. R.S.Shanmugasundaram and Dr. S.Lakshmi, Neonatologists; Dr. E. Mahender and Dr. V. Poovazhagi, Pediatricians.

**Bibliography**

**Glucometer**


**Useful websites**

1. www.bayerdiag.com/
2. www.morepen.com/maniranini.htm
3. www.abbottdiabetescare.com
4. www.ascenasia.com
5. www.lifescan.com
6. www.abbott.com

**Cold light source**

1. Respiratory problems and their management from NICCU clinical Guidelines Section 2 from King Edward Memorial/Princess Margaret Hospital, Perth, Western Australia


**Urine diagnostic**

1. Urine testing—Quick Reference guide in Nursing Standard 1999;13:


**Useful website:** www.uritest.com
NEONATAL CENTRAL LINES

*Srinivas Murki*

**Abstract:** Central lines have become an essential component of intensive newborn care. To optimize the use of central lines in neonates, one should thoroughly know the indications, techniques of insertion, line maintenance and complications. In this article, the use of central venous lines in neonates is reviewed.

**Key words:** Central venous lines, Neonate

Critically ill infants often require intravenous access for an extended period of time. Central venous (CV) lines have become an increasingly common mode of treatment for neonates who require total parenteral nutrition, long-term antibiotic treatment, continuation of locally toxic medications such as dopamine and difficulty with repeated peripheral access. Use of central venous lines reduces the need for repeated venipuncture but is associated with complications such as line migration, infections, thrombosis, extravasations, pericardial effusion/tamponade, embolization etc.

**Indications of CV lines**

1) To provide secure venous access for administration of fluids and parenteral nutrition (PN) when enteral nutrition will not be possible for few days. 2) To enable the safe and uninterrupted administration of clinically essential and locally toxic medications such as inotropes and concentrated dextrose solutions. 3) As a mode of venous access when peripheral lines have been exhausted. 4) Other uncommon uses include exchange transfusion, central venous pressure monitoring, cardiac catheterization and hemofiltration.

**Types of CV lines**

There are three major types of central venous access in neonates.

1. **Umbilical venous catheters (UVCs):** These are relatively easy to insert and are the common lines inserted in the first week of life. Common umbilical lines inserted are 3Fr or 5Fr and are either made of polyvinyl chloride or polyurethane. Multi-lumen catheters are useful in sick neonates for concomitant administration of fluids and medications. Single lumen UV lines are easily available and cost less than Rs.150 (Table 1).

2. **Peripherally inserted central catheters (PICC):** These catheters are now easily available and form the choice of most neonatologists. PICC lines are commonly inserted into the cephalic or basilic veins in the upper limbs and rarely into the saphenous vein in the lower limb. PICC lines are made of silicone or polyurethane, available as single lumen or multi-lumen and introducer needle could be splitting type. 27G catheters are useful for extreme preterms (less than 800g) and 22G or 23G catheters for larger neonates. PICC lines cost anywhere from Rs.1400 to Rs.4200.

3. **Surgically inserted central lines:** These are inserted after direct cut down and this is done using a Hickman or Broviac catheter into the...
jugular vein. With the availability of PICC lines the need for surgically inserted lines has decreased.

**Technique and steps of insertion**

**Umbilical venous lines:** Place infant in supine position under radiant warmer. Measure the shoulder to umbilical distance and determine the length of catheter to be inserted after adding the length of umbilical stump (Fig.1). Hand wash for 2 minutes. Wear cap, mask, gown and gloves. Clean the cord, and peri-umbilical area with betadine (wait till it dries) or 0.5% chlorhexidine antiseptic solution and then with spirit. Establish sterile field with drapes. Cut the clamped cord approximately 1cm above the stump and identify the thin-walled umbilical vein (cord has 2 thick walled arteries and 1 thin walled vein). Hold the umbilical cord with a toothed forceps and introduce an iris forceps into the vein. Dilate the vein by guiding the forceps above and towards the right shoulder (course of umbilical vein). Fill a 3Fr or 5Fr catheter with normal saline and gently introduce the fluid-filled catheter, attached to a syringe, 2-3cm into the vein. If some resistance is met at the abdominal wall, apply traction up and caudal to the cord while continuing gentle pressure on the catheter. Insert catheter for full estimated distance and apply gentle suction to the syringe during insertion. Ensure a free flow of blood into the catheter. Obtain an x-ray for verification of catheter tip. The desired location is T9-10, just above the right diaphragm. Once catheter position is confirmed, fix using the Golf post technique. Document in file, date and time of insertion, length of insertion, number of attempts, catheter tip position and ‘check x-ray’ findings.

**Precautions for UVC:** UVC is contraindicated in the presence of abdominal wall defect (e.g. Omphalitis, omphalocele, gastroschisis), necrotizing enterocolitis and peritonitis. Complications of UVC include

<table>
<thead>
<tr>
<th>Birth weight</th>
<th>Age</th>
<th>CV line</th>
<th>Size</th>
<th>Available brands</th>
<th>Cost *</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;800gms</td>
<td>&lt;3days</td>
<td>Umbilical</td>
<td>3Fr</td>
<td>Vygon, Romsons</td>
<td>Rs. 150</td>
</tr>
<tr>
<td>&lt;800gms</td>
<td>&gt;3days</td>
<td>PICC</td>
<td>27G/20cm, 24G/15cm,30cm, 22G/12cm, 22G/13cm, 22G/10, 20cm</td>
<td>Premicath, Neocath, Leaderflex, Arrow, BD</td>
<td>Rs.3600, Rs.1400, Rs.1400, Rs.1200</td>
</tr>
<tr>
<td>&gt;800gms</td>
<td>&lt;3days</td>
<td>Umbilical</td>
<td>5Fr</td>
<td>Vygon, Romsons</td>
<td>Rs. 150</td>
</tr>
<tr>
<td>&gt;800gms</td>
<td>&gt;3days</td>
<td>PICC</td>
<td>23G/30cm, 22G/12cm, 22G/20cm, 22G/12cm, 22G/20cm</td>
<td>Nutrine, Leaderflex, Centracath, Arrow, BD</td>
<td>Rs.4700, Rs.1400, Rs. 450, Rs.1200</td>
</tr>
</tbody>
</table>

*Costs are approximate.*
infections, thromboembolism, catheter malposition in heart or great vessels or in portal system, perforation of the peritoneum, obstruction of pulmonary venous return and portal hypertension.

3) To reduce the complications ensure:
   a) Catheter tip must go through the ductus venosus in order to prevent accidental cannulation of the hepatic vessels or portal vein.
   b) The catheter tip should lie in the inferior vena cava at the level of T10 as confirmed by x-ray.
   c) The catheter tip should not sit higher than this as it is also hazardous to have the tip sitting at the foramen ovale.
   d) If the catheter tip cannot be placed in the inferior vena cava, the tip should be low enough to avoid the portal circulation. This is usually achieved with an insertion to approximately 2 cm from the skin level. It should be very easy to draw blood or infuse with a syringe. The catheter can be secured and used for infusion of fluids and medications (even exchange transfusions), but will not give an accurate CVP. The line cannot be used for the infusion of hypertonic solutions if the catheter tip is not in the inferior vena cava.
   e) Do not leave the catheter open to atmosphere (danger of air embolus).
   f) Avoid use of CVP monitoring catheter for concomitant infusion of parenteral nutrition.

**Peripherally inserted central catheters (PICC):** Place the infant in optimal position (Fig.2). For basilic or the cephalic veins, rotate the head towards insertion site with chin on shoulder and abduct the arm to 90°. Sedate with 0.1mg/kg of midazolam or with 1-2µg/kg of fentanyl. Measure the length of the catheter to be introduced. (Insertion site to the mid sternal notch for upper limb insertion and from insertion site to 2 cm above the umbilicus for lower limb insertion). Wash hands for 2 minutes, wear cap, mask, gown and gloves. Prepare the PICC line and prime with normal saline using 5ml syringe and connect the catheter to the syringe. Clean the insertion site with betadine and then with spirit. If available use 0.5% chlorhexidine in place of betadine. Apply a tourniquet above the
insertion site with a pressure just to occlude the vein and make it prominent. Stabilize the arm (with an assistant), puncture the basilic or cephalic vein with an introducer needle. Another option is to use 22G venflon in place of the introducer needle. Pass the guide wire through the introducer needle/venflon and then pull out the introducer needle or venflon. Slowly and gently thread the catheter over the guide wire into the vein. Maximum care should be taken when the catheter pierces the skin (a small nick can be given on the skin at the insertion point for easy threading of the catheter). Once the catheter is threaded over the guide wire to the desired length, remove the guide wire and ensure free flow of blood into the catheter. If resistance is met while threading the catheter, flush with normal saline and advance gradually. Apply pressure to stop bleeding at the insertion site before securing catheter to skin. Confirm the tip of PICC line with an X-ray before connecting the infusate. The catheter tip should be in the superior vena cava outside the pericardial reflection and above T2. Sometimes use of contrast or lateral radiographic views may be helpful to determine the catheter tip position. Dress the insertion site with a tegaderm and connect the infusate to the catheter hub.

Note: When using Nutriliner (23G/30cm) or the Premicath (27G/20cm) catheters they can be threaded through the introducer needle directly and once the catheter is advanced to the desired length, remove the introducer needle, split it and peel it off the catheter.

**Maintenance and complications of PICC lines**

- In addition to monitoring of the catheter tip, PICC insertion site and track of the vein should be monitored for erythema, drainage or edema.
- The line should be continuously flushed with normal saline or attached to a maintenance/heparin line at a minimum rate of 1ml/hour to prevent venous thrombosis.
- PICC related sepsis can be minimized by using polyurethane or silicon catheters, decreasing line breaks for infusion change or for medications, using single lumen in place of multi-lumen catheter, shortening the duration of line use and staff education.
- When using PICC lines, persisting sepsis (repeat blood culture positive) after starting appropriate antibiotics should be an indication to remove the catheter.
- Wrong catheter tip position leads to extravasations and hence all steps should be taken to prevent the tip position in a small vein or into the cardiac chambers.
- Pericardial effusions resulting in tamponade may be more likely when the catheter tip lies within the cardiac silhouette, particularly if there is a length of free catheter within the heart. Positioning the line tip outside the heart does not completely prevent cardiac tamponade and may cause other serious complications. Early signs of pericardial effusion should be recognized, including unexplained cardiovascular decompens-
sation and enlarging cardiac silhouette on x-ray examination.

- Line migration distally or more proximally into the cardiac chambers can be decreased by stabilizing the arm.

- Air embolism or embolism of catheter fragment has been associated with prolonged use of PICC lines, line occlusion or difficulty with catheter removal.

Evidence: Central lines in neonates

1. PICC lines provide long-term access necessary for the administration of total parenteral nutrition (TPN) and medications and reduce the need for venipuncture and extended use of umbilical catheters.

2. Tetracaine 4% when applied for 30 minutes before catheter insertion, is not beneficial in decreasing procedural pain associated with a PICC in very small infants.

3. The risk of perforation and tamponade is especially high in small weight premature with 27 gauge polyurethane catheters when tip was located in the cardiac cavities. In children and adults venous thrombosis and catheter malfunction are closely related to short catheters whose tip is above T3-T4. The best location of long-term central venous catheters tip is the superior vena cava-right auricle junction.

4. The use of ML(Multiple Lumen)-UVCs in comparison to SL(Single Lumen)-UVCs in neonates is associated with decrease in the usage of peripheral intravenous lines in first week of life, but an increase in catheter malfunctions.

5. Incidence of sepsis or death is similar between the groups with PICC line and with peripheral intravenous lines (PIV). PICC line decreases the skin punctures required for intravenous access.

6. Prophylactic use of a vancomycin-heparin lock solution reduces the incidence of catheter related blood stream infections in high risk neonates. There is no increase in vancomycin resistance but is associated with asymptomatic hypoglycemia.

7. Central venous catheters coated with chlorhexidine/silver-sulfadiazine reduces the incidence of catheter-related bloodstream infections.

8. Heparin infusion (0.5 U/kg per hour) prolongs the duration of peripherally inserted central venous catheters, permits a higher percentage of neonates to complete therapy without increasing adverse effects. In the study by Shah, et al for those in the heparin versus the placebo group, the incidence of elective catheter removal (therapy completed) was 63% vs 42%, occlusion was 6% vs 31%, thrombosis was 20% vs. 21%, and catheter-related sepsis was 10% vs 6%, respectively. No adverse events were noted.

Points to Remember

- Central venous catheters in neonates fall into three major categories namely 1) Umbilical venous catheters (UVC) 2) Peripherally inserted central catheters and 3) Surgically inserted catheter lines.

- If correct indications and proper techniques are adhered to, UVC and PICC replace the need of surgically inserted catheter lines.

- Stringent care is to be taken to avoid complications and to tackle effectively if they occur.

References


---

**NEWS & NOTES**

**MADURAI PEDICON 2008**

33rd ANNUAL STATE CONFERENCE OF IAP- TAMILNADU STATE CHAPTER

Date: 8th – 10th August 2008

Venue: Lakshmi Sundaram Hall, Madurai

Contact

**Dr.R.Mahalingam**
Organising Secretary
Institute of Child Health and Research Centre
Govt. Rajaji Hospital, Madurai
Mobile No: 93676 76007.
E-Mail: iaptnmadurai@yahoo.com

**Dr.S.Shanmugasundaram**
Mobile No: 93441 00558
MONITORING EQUIPMENTS IN PEDIATRIC INTENSIVE CARE UNITS

* Anil Sachdev  
** Vikas Bansal

Abstract: Intensive and continuous monitoring is integral part of critical care services. Vital signs can be monitored continuously, accurately and noninvasively by using various equipments in intensive care units. Readings provided by monitors should always be interpreted in association with patient’s clinical condition. A single multichannel monitor can monitor a variety of vital parameters simultaneously. Basic knowledge of physical principles and advantages of monitoring equipments is required to give maximum benefit to patient. While purchasing equipments one should consider medical requirements and check credentials of manufacturing and marketing companies.

Key words: Pediatric intensive care, Monitoring, Equipment.

When intensive care units (ICUs) came into being in the late 1950s, vital signs were monitored intermittently by a nurse, and continuous monitoring was either unavailable or necessitated invasive procedures. The explosion of knowledge in the use of computers and other technology over the past few decades has significantly changed critical care management. All vital signs can now be monitored accurately, noninvasively and continuously.

PULSE OXIMETER

Pulse oximetry is a simple non-invasive method of monitoring the percentage of hemoglobin (Hb) which is saturated with oxygen. The pulse oximeter consists of a probe attached to the patient’s finger or ear lobe which is linked to a computerized unit. The unit displays the percentage of Hb saturated with oxygen together with an audible signal for each pulse beat, a calculated heart rate and in some models, a graphical display of the pulse waveform.

A source of light originates from the probe at two wavelengths (660nm and 940nm). Oxygenated hemoglobin in the pulsatile tissue bed primarily absorbs infrared light (940nm) and reduced hemoglobin absorbs red light (660nm). By calculating the absorption at the two wavelengths the processor can compute the proportion of hemoglobin which is oxygenated (Fig 1 and 2). The oximeter is dependant on a pulsatile flow through capillary bed and produces a graph of the quality of flow. Where flow is sluggish (eg. hypovolemia or vasoconstriction) the pulse oximeter may be unable to function. The microprocessors within the oximeter is capable of distinguishing pulsatile flow from other more static signals (such as tissue or venous signals) to display only the arterial flow.

Clinical use and limitations

Oximeters are calibrated during manufacturing and automatically check their internal circuits when they are turned on. They
are accurate in the range of oxygen saturations of 70 to 100% (+/-2%), but less accurate under 70%.

Continuous pulse oximetry is a very useful tool for monitoring both oxygen saturation and heart rate. It is particularly important in emergency room, intensive care units, operation rooms and postoperative recovery rooms. Saturation monitoring should be done in all patients, attending emergency and admitted in ward and recorded in nurse vital chart. It is of great help when children are undergoing diagnostic procedures under sedation like endoscopy, bronchoscopy, bone marrow aspiration and liver and renal biopsy.

Oximetery has few limitations. It gives no information about the level of CO₂ and therefore has limitations in the assessment of patients developing respiratory failure due to CO₂ retention. Pulse oximeter cannot detect hyperoxia which can be very detrimental in neonates. PaO₂ of more than 75mmHg corresponds with saturation of 100%. On occasions oximeters may develop faults, so the reading should always be

---

Fig 1. Sources of absorption in tissue bed during the use of pulse oximetry.

Fig 2. The pattern of light reflection by oxygenated hemoglobin (HbO₂) and deoxygenated hemoglobin (Hb). The vertical lines represent the two wavelengths of light (660 nm and 940 nm) used by pulse oximeters.
Table 1. Conditions leading on to faulty reading in pulse oximeter

<table>
<thead>
<tr>
<th>Poor / faulty signal detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Movement, 2) Probe malposition, 3) Hypothermia, 4) No pulse, 5) Vasoconstriction, 6) Hypotension</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abnormal SPO₂ reading / false low SPO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Nail polish, 2) Dark skin, 3) Ambient light, 4) Elevated serum lipids, 5) Methylene blue, 6) Indigo carmine, 7) Indocyanine green</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>False high SPO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Elevated carboxyhemoglobin, 2) Elevated methemoglobin, 3) Ambient light, 4) Hypothermia</td>
</tr>
</tbody>
</table>

interpreted in relation with the patient’s clinical condition. Conditions in which problems are encountered in use of pulse oximeters are described in Table 1.

One should never ignore a reading, which suggests the patient is becoming hypoxic.

MULTICHANNEL MONITOR

Over the past several years, the trend in monitoring systems has been to become multipurpose. This means that one system monitors a variety of parameters. Commercial systems now have the ability to monitor multiple parameters both by invasive and noninvasive means like blood pressure, dual temperature, respiration, oxygenation, end-tidal carbon dioxide, mixed venous oxygen saturation, electro-cardiographic (ECG) rhythm and ST segment analysis. Few sophisticated monitors also have the facility to display continuous EEG and intracranial pressure and cerebral perfusion pressures. A multipurpose system eliminates the need for multiple, freestanding devices and makes it easier to coordinate the monitoring of different parameters.

ELECTROCARDIOGRAPHIC MONITORING

Continuous ECG monitoring is performed routinely in almost all PICUs. ECG monitoring in most ICUs is done over hard-wired apparatus. Skin electrodes detect cardiac impulses and transform them into an electrical signal, which is transmitted over wires directly to the signal converter and display unit. This removes the problems of interference and frequency restrictions.

Multichannel monitors can also have the additional features of arrhythmia monitoring.

The software in these systems is capable of diagnosing arrhythmias based on recognition of heart rate, variability, rhythm, intervals, segment lengths, complex width and morphology. Full disclosure capabilities can provide invaluable review of subtle physiological changes which led to an arrhythmia event. Full 12 lead ECG should be obtained wherever possible because some diagnostic details like QRS aberrancy, atrial rate and P wave morphology may be evident only in selected leads.

BLOOD PRESSURE MEASUREMENT

Non invasive blood pressure measurement (Automated methods)

Automated indirect blood pressure devices provide measurements of arterial blood pressure without manual inflation and deflation of the sphygmomanometer cuff. They operate on one of seven principles: Doppler flow, infrasound,
Oscillometry, volume clamp, arterial tonometry, doppler echocardiography and pulse wave arrival time.

**Oscillometry**

This principle is most commonly used in modern NIBP devices. The cuff senses pressure fluctuations caused by vessel wall oscillations in the presence of pulsatile blood flow. Maximum oscillation is seen at mean pressure, whereas wall movement greatly decreases below diastolic pressure. The signals produced by the system are processed electronically and displayed in digital form. One of the proposed advantages of automated noninvasive monitoring is patient safety. The incidence of vessel occlusion and hemorrhage is thought to be reduced when arterial lines are avoided. Automated methods have complications of their own. Ulnar nerve palsies have been reported with frequent inflation and deflation of a cuff. Decreased venous return from the limb and eventually reduced perfusion to that extremity can also be seen when the cuff is set to inflate and deflate every minute (Fig.3).

Oscillometric devices do not perform well if there is significant limb movement or in presence of dysrrhythmias. Accuracy and sensitivity of occlusive devices decrease in severe hypoperfusion. Appropriate cuff size is required for measuring blood pressure. Oversized cuff will artificially give a low blood pressure reading and vice versa but the magnitude of error is small.

**Direct invasive blood pressure measurement**

Direct blood pressure measurement is performed with an intra arterial catheter. Arterial catheter is connected to a fluid filled tube that transmits the pressure to an electronic transducer. A low compliance diaphragm in the transducer creates a reproducible volume change in response to the applied pressure change. The volume change alters the resistance of a Wheatstone bridge and is thus converted into an electrical signal. In most monitors, the pressure is displayed in wave and in digital forms.

Arterial lines actually measure the end-on pressure propagated by the arterial pulse. This is

![Fig.3. Illustration of the relationship between the oscillometric determination of blood pressure and the blood pressure waveform](image-url)
in contrast to indirect methods, which report the external pressure necessary either to obstruct flow or to maintain a constant transmural vessel pressure. Arterial lines can also detect pressures at which Korotkoff sounds are either absent or inaccurate. Arterial lines provide a continuous measurement. They provide an immediate report of changes in blood pressure without the need for repeated inflation and deflation of a cuff. In situations in which frequent blood samples are necessary, indwelling arterial lines eliminate the need for multiple percutaneous punctures. Fig.4 shows normal arterial waveforms.

**Problems related to direct blood pressure monitoring**

1) Transducers must be calibrated to zero at the level of the heart. Improper zeroing can lead to erroneous interpretation of essentially accurate measurements.

2) Thrombus formation at the catheter tip can cause occlusion of the catheter, making accurate measurement impossible. A slow continuous heparin flush using a 20-gauge polyurethane catheter can largely eliminate this problem.

3) Limb movements lead to inaccurate measurement. Limb should be immobile during readings.

4) Air bubble in the tubing system can lead to damped analog waveform and erroneous pressure measurement (Fig.5).

5) Arterial catheter can lead to local site infection and thrombophlebitis. It can also lead to severe systemic infection and sepsis.

Radial and femoral artery are the commonest sites of arterial cannulation. Other available sites include dorsalis pedis, and axillary arteries. Allen test must be performed before cannulating radial artery, to check the presence of collateral blood supply. Systolic pressures measured in the radial artery are, on average, 6 mm Hg higher than those in the brachial artery. Similarly, in the absence of a significant arterial obstruction, dorsalis pedis pressures are higher than femoral pressures. These differences are less significant in older patients and those with noncompliant vessels (Fig.6). The mean arterial pressure (MAP) does not vary along the course of the arterial tree, making it a more accurate indication of the pressure in the aorta.
Transcutaneous systems

They measure partial pressures of oxygen (PtCO\(_2\)) and carbon dioxide (PtcCO\(_2\)) that diffuse out of the vasculature and through the skin.

The technology used to obtain transcutaneous gas measurements varies slightly between manufacturers but in general uses similar techniques. Probe less than 1 inch in diameter is attached to the skin with an adhesive. An electrode is used to heat the skin, which promotes arterialization of capillaries and improves diffusion of gases through its fat layer. A temperature sensor measures skin temperature at the skin surface and adjusts the heater to provide a constant temperature. Temperature of 43.5\(^\circ\) to 44.5\(^\circ\)C produces the most satisfactory results\(^7\). Similar results may be produced by stripping off the stratum corneum with adhesive tape or measuring from a site with a thinner layer of skin, such as the conjunctiva. Precalibrated Clarke and Severinghaus type electrodes, similar to those used in blood gas machines, measure the partial pressure of oxygen and carbon dioxide. These signals are then electronically averaged and converted into a continuous digital display. Alarms can be set for high and low values of both gases measured. Many units also display trend signals. Because units use electrodes for partial pressure measurement, problems with calibration and electrode drift during prolonged monitoring can clearly alter measurements. Drift may alter readings by up to 12% over a 2-hour period\(^7\). Transcutaneous measurements are adversely affected with increased probe temperature, hypoperfusion state, changes in local metabolism of measuring site and in altered state of skin like presence of edema, burns and sclerema. Skin burn is a serious complication especially in infants and neonates.

Indications

Transcutaneous monitoring is most useful in stable patients for continuous monitoring of oxygenation and ventilation status. Transcutaneous PCO\(_2\) monitoring is very useful in patients requiring high frequency oscillation ventilation as end tidal carbon dioxide pressure (ETCO\(_2\)) cannot be measured in these patients.

CAPNOGRAPHY

Capnography involves the measurement and display of expired CO\(_2\) concentrations. Expired CO\(_2\) concentration is usually determined by infrared absorbance or mass spectrometry. The infrared technique relies on the fact that carbon dioxide has a characteristic absorbance of infrared light, with maximal absorbance near a wavelength of 4.28 nm. A heated wire with optical filters is used to generate an infrared light of appropriate wavelength. Two types of expired air sampling methods are used (Table 2).
Differences between end-tidal and arterial carbon dioxide

The end alveolar plateau level of CO₂ measured during the last 20% of exhalation is the end-tidal CO₂. In normal person at rest, the difference between end-tidal CO₂ and PaCO₂ is ±1.5 mm Hg. A difference exists because of the presence of dead space (i.e., ventilation without perfusion) and a physiologic shunt (i.e., perfusion without ventilation). Any change in anatomic dead space or pulmonary perfusion alters ventilation-perfusion mismatch so as to increase the difference between end-tidal and arterial PCO₂ values. As the dead space increases, CO₂ concentration in expired air decreases due to ventilation of non perfused alveoli thus creating difference between ETCO₂ and PCO₂. As perfusion decreases, fewer alveoli are perfused, creating a similar effect (Fig.7).

Indications

1) Capnography is most useful for determining the presence or absence of respiration. It is a useful adjunct for detecting unintentional extubation, malposition of the endotracheal tube and absence of perfusion.

2) Difference between end-tidal CO₂ and PCO₂ can be used as an index of the severity of ventilation-perfusion mismatch and helps in calculation of dead space.

Information about equipments

A variety of monitoring equipments for ICU are available in Indian market promoted by different companies. Most of these equipments are imported. One should be careful in selecting specific equipments and check the manufacturing and marketing companies’ credentials and after sale services. For example a variety of pulse oximeters are available from brands like Nelcor, Respironics, Nonin, Welch Alleyn and others. The cost varies from Rs 8,000 to Rs 50,000 depending upon the brand and the sophistication of the product. Disposable and re-usable finger probes are available. Re-usable probes require cleaning with chlorhexidine.

Multi-channel monitors are manufactured by various companies like DASH 4000(GE); Solar 8000(GE); Larsen & Tubro and others. The cost depends upon sophistication and the number of parameters monitored. All the equipments in PICU do need maintenance like regular battery replacement and repairs.

Table 2. Differentiation of sampling methods available for end tidal CO₂ measurement

<table>
<thead>
<tr>
<th>Mainstream capnometer</th>
<th>Sidestream capnometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Capnometer placed in line with respiratory circuit. Used only in intubated patients or with tight fitting face or nose mask.</td>
<td>1) 100 to 300 ml expired air/ minute pumped to side stream capnometer.</td>
</tr>
<tr>
<td>2) Does not affect the tidal volume</td>
<td>2) Confounds measurements of tidal volume</td>
</tr>
<tr>
<td>3) Detects changes in carbon dioxide rapidly without delay.</td>
<td>3) Aspiration flow rate and tubing length proportionately affects the detection of changes in carbon dioxide.</td>
</tr>
<tr>
<td>4) Pulmonary secretions, saliva or water condensation can affect calibration</td>
<td>4) More prone to clogging with secretions and water condensation.</td>
</tr>
</tbody>
</table>
Gradual increase in ETCO$_2$
- Hypoventilation
- Partial obstruction
- CO$_2$ reabsorption

Gradual Lowering of ETCO$_2$
- Hypovolemia
- Decreasing cardiac output
- Drop in metabolism

Constantly high ETCO$_2$
- Respiratory depression
- Metabolic alkalosis
- Low minute ventilation

Sudden increase of ETCO$_2$
- Release of tourniquet
- Sudden increase in blood pressure

**Fig. 7. ETCO$_2$ waveforms and their interpretation**

**Points to Remember**
- Intensive and continuous monitoring is integral part of critical care services for early detection of physiological changes due to progress of disease or adverse effects of any therapeutic intervention.
- Care provider must understand and learn the physical principles, advantages and limitation of a particular equipment to give maximum advantage to patient.

**References**


OBITUARY

Dr. S. Jayam, a renowned senior Pediatrician and Neonatologist was born on 4th August 1939 and reached heavenly abode on 5th Jan 2008 at Chennai after a brief illness. Dr. S. Jayam was the best outgoing student and gold medalist of Madurai Medical College during her undergraduate course. She was the post graduate student of the great Dr. S. T. Achar and trained by Dr. Nagasamy the first neonatologist of Tamilnadu. She had a brilliant academic career and served the Government of Tamilnadu in various capacities and retired as the Director, Institute of Child Health and Hospital for Children, Chennai, Madras Medical College. She was a teacher par excellence and many pediatricians have had the good fortune of being trained by her. She was one of the Pioneers in Neonatology in Tamilnadu and India. During her tenure in Government service she had helped in building many neonatology units not only in medical colleges but also at various district hospitals. She had also executed many National and International projects with WHO, UNICEF and RCH. She had formulated many cost effective neonatal interventions which could be easily replicated to reduce Neonatal mortality. She was an active member of many Academic bodies like IAP, NNF and BPNI and had held various offices in these fora. She was also the past president of NNF. She was the recipient of many awards and distinctions during her career. She was the Founder, Director of Sahishnatha Educational and Charitable Trust at Vijaya group of hospitals following her retirement and was totally committed to holistic care of children both at primary and tertiary level. The ideals for which she stood will continue to inspire many generations of pediatricians.

“May her soul rest in peace”
EQUIPMENT UPDATE

PRELIMINARY MEDICAL ACCESSORIES

*Sunil Srinivasan

Abstract: Digital weighing machines are convenient and accurate for all ages. Infantometer used to measure the length of infants and stadiometer used for accurate height measurement are essential accessories in pediatric practice. Though rectal thermometers are still the standard for measuring temperature, tympanic infrared thermometers are convenient and the readings approximate core temperatures. The standard mercury sphygmomanometer is still the most accurate method of measuring blood pressure, in spite of newer digital electronic machines.

Key words: Weighing machine, Stadiometer, Thermometer, Sphygmomanometer

In this article, the following will be discussed 1. Weighing machines, 2. Infantometer and Stadiometers, 3. BP apparatus, 4. Thermometers

WEIGHING MACHINES

Accurate weight measurements are an integral part of pediatric practice. Now that growth charts have been incorporated in the official IAP office practice software, regular weight recording will automatically generate the relevant growth charts.

The 3 types of weighing machines used commonly are a) Spring balance type, eg. baby weighing scales and bathroom scales, b) Beam balance type, eg. commercial use in railway platforms, and c) Digital type.

Baby weighing scales

They are the most practical way of weighing infants and babies weighing less than 10 kg. With use the spring becomes loose and the weight readings are no longer accurate. Moreover the pan wobbles with time, and care should be taken while weighing a vigorous crying infant.

It is preferable to use disposable sheets between weighing babies, but is often not practical. Standardization of the instrument by periodic checks with known weights as well as annual stamping with the local metric measures authority will help to ensure accuracy. Electronic baby weighing scales accurate upto 1 g are very useful in monitoring preterm babies (Fig.1).

Bathroom Scales

They are popular and inexpensive, but are notoriously error prone. Inter observer variation is high and the needle also is unsteady with heavier patients. Being spring type of balance, it loses accuracy over time. The observer has to adopt a difficult bending posture to read the scale correctly and often there are parallax errors while doing so. In spite of all these limitations, bathroom scales are widely used in hospitals. In situations where weight recording is crucial for diagnosis or treatment, eg. documenting weight loss or calculating fluid requirement, it is wise
to recheck the weight yourself, or use a digital machine.

**Digital Machines**

They are the best in terms of accuracy and ease of reading. With the modern parents demanding digital weight recording, it is prudent to buy one of this as early as possible. With models ranging from Rs 8000 - Rs.18000, it is often difficult to decide which one to buy. However along with this comes the space problem, and you have to plan where to keep the machine, and how to get it electrically connected. Children, parents and the receptionists are notoriously indifferent to the sensitive and fragile nature of these instruments. Hence it is wise to place these machines safely in the consulting room. The digital reading box can be kept at any convenient place and not necessarily by the side of the weighing platform. A combined standing, seating and baby pan model (aprx Rs.20000) is available, as are standing models with protective handrails. These are fairly sturdy and last for many years without much problem. A comparison of various types of weighing machines is given in Table 1.

**HEIGHT AND LENGTH MEASUREMENT**

**Stadiometer**

The common practice of fixing a height chart on a wall and placing a ruler or a pencil over the head of the child whose height has to be measured, is inaccurate. It is cumbersome, error prone and has often differences upto 5 cm when measured by different individuals. Hence stadiometer is used to measure the height accurately. It is a simple device which has a fixed wooden or aluminum height scale along with a sliding head platform (Fig. 2). Again, in the new IAP Pediatric office software, automatic height charts are generated, when serial height measurements are recorded.

**Infantometer**

Are used to measure the length of infants, before they can stand. It is particularly used for knowing the growth of LBW babies. The infant

![Fig.1. Electronic Baby weighing scale (1. Baby pan, 2. DC adaptor(9v), 3. Display panel, 4. Keyboard, 5. Body, 6. Levelling leg).](image1)

![Fig.2. Stadiometer](image2)
is placed on a clean cloth placed over the infantometer, the head abutting the fixed head end of the scale and the foot plate adjusted over the stretched legs (Fig. 3). With crying babies, it needs an assistant as well as some practice to learn the technique.

**Table 1. Types of weighing machines**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Baby weighing machine</th>
<th>Bathroom scales</th>
<th>Digital machines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode of operation</td>
<td>Spring type</td>
<td>Spring type</td>
<td>Chip</td>
</tr>
<tr>
<td>Indications</td>
<td>Infants</td>
<td>1-18 yrs</td>
<td>Any age</td>
</tr>
<tr>
<td>Advantages</td>
<td>Cheap</td>
<td>Cheap</td>
<td>Easily readable by</td>
</tr>
<tr>
<td></td>
<td>Easily available</td>
<td>Easily available</td>
<td>Parents</td>
</tr>
<tr>
<td></td>
<td>Little maintenance</td>
<td>Little maintenance</td>
<td>Accurate</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>Spring becomes loose</td>
<td>Spring becomes loose</td>
<td>Expensive</td>
</tr>
<tr>
<td></td>
<td>Platform wobbly with use</td>
<td>Needle shakes</td>
<td>Needs electrical connection</td>
</tr>
<tr>
<td>Cost</td>
<td>Approx Rs 800</td>
<td>Approx Rs 800</td>
<td>Approx Rs.10000</td>
</tr>
<tr>
<td>Annual maintenance</td>
<td>Nil except local stamping (Rs.300/-)</td>
<td>Nil except local stamping (Rs.300/-)</td>
<td>Contract Rs.2000 approx annually</td>
</tr>
<tr>
<td>Brands</td>
<td>KRUPPS</td>
<td>KRUPPS</td>
<td>ATCO, ESSAE</td>
</tr>
<tr>
<td>Spare accessories</td>
<td>Nil, disposable sheets over the pan</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>Cleaning</td>
<td>Soap and water</td>
<td>Soap and water</td>
<td>Soap and water</td>
</tr>
<tr>
<td>New developments</td>
<td></td>
<td></td>
<td>3 in 1 combined model, handrails</td>
</tr>
<tr>
<td>Observer error</td>
<td>Upto 0.5 kg</td>
<td>Upto 3kg</td>
<td>Nil</td>
</tr>
<tr>
<td>Reliability</td>
<td>Fair</td>
<td>Fair</td>
<td>Good</td>
</tr>
</tbody>
</table>
THERMOMETERS

The study of thermometers is expanding rapidly to merit a separate field called thermometry. For routine purpose, the following are considered 1) Mercury in glass (axillary, oral and rectal), 2) Scans, 3) Digital (axillary, oral and rectal), 4) Tympanic membrane

Mercury

This has been universally used for decades. However recent concerns about mercury and environment pollution has made many Western hospitals adopt a “no mercury” policy. In India, there is still widespread use of mercury in glass thermometers, due to availability, familiarity and cost factors.

Axillary: It is commonly practiced in the OP setting, is prone to errors and observer variations. However, it is well accepted by parents and needs minimal disturbance of the child. It should be kept for at least 2 minutes before reliable readings can be obtained. Care is to be taken to shake the thermometer well before use, so that the mercury level is brought below the normal marking, before using it. A recent study suggests that axillary thermometers be kept for at least 8 minutes, which is not practical\(^1\).

Oral route: Oral temperature is closer to core temperature, but again prone to fallacies. Consumption of hot liquids before the reading will give a false high value, while dehydration and mouth breathing will give a false lower value. The disadvantages of non cooperation of an already sick child, possibility of breakages in a resisting child, and the fear of infection transmission, makes this route not acceptable to many.

Rectal: Once considered as the gold standard, this has fallen into disrepute, following newer methods, and concerns about mercury, infection transmission, patient discomfort and injuries. The instrument is easily distinguishable by the short bulb. It is more useful in measuring core temperature in hypothermia, especially in neonates, though skin sensors have largely replaced the rectal thermometers. The normal range and relationship is given in the Table 2\(^2,3\).

<table>
<thead>
<tr>
<th>Normal range</th>
<th>94.5-99.1°F</th>
<th>34.7-37.3°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axillary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oral</td>
<td>95.9-99.5°F</td>
<td>35.5-37.5°C</td>
</tr>
<tr>
<td>Rectal</td>
<td>97.9-100.4°F</td>
<td>36.6-38°C</td>
</tr>
<tr>
<td>Tympanic</td>
<td>96.4-100.4°F</td>
<td>35.8-38°C</td>
</tr>
</tbody>
</table>

The relationship

<table>
<thead>
<tr>
<th>Rectal</th>
<th>STANDARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral</td>
<td>0.5-0.6°C (1°F) lower</td>
</tr>
<tr>
<td>Axillary</td>
<td>0.8-1.0°C (1.5-2°F) lower</td>
</tr>
<tr>
<td>Tympanic</td>
<td>0.5-0.6°C (1°F) lower</td>
</tr>
</tbody>
</table>
**Scans**

They are temperature sensitive liquid crystal containing strips that can be placed over the forehead, and the reading obtained within seconds. Though commercially popular, they are highly erroneous. A study done in Indian subcontinent showed fever scans overestimated the temperature and hence not reliable⁴.

**Digital thermometer**

It is gaining popularity, because of user friendliness, readability, unbreakable nature and acceptability by parents (Fig.4). Again there are axillary, oral and rectal routes, with respective advantages and disadvantages as discussed above. In routine OP practice axillary digital thermometers are highly useful and liked by both nurses and parents. Most of these thermometers give a beep after every 4 seconds followed by a long completion beep once the required 2 minutes time is over, thereby assuring proper technique. The digital thermometer can also be used rectally after applying a water-soluble jelly on it. The baby can be placed on the sides or on his/her abdomen with legs hanging down. The tip is gently inserted for about ½ inch. Obviously this cannot be used orally for subsequent use!

**Tympanic infrared thermometers**

Measures the infrared heat generated by the eardrum and surrounding tissues (Fig.5). As eardrum shares blood supply with the...
hypothalamus, it reflects the core temperature more accurately. Before using the probe, it has to be warmed to a temperature close to human body, to ensure accuracy. Presence of wax, or recent bath or swimming may affect the readings. Tympanic thermometers are not suitable for young infants and some study report even upto 3 years. Tympanic thermometer reading correlate well with rectal readings in Indian children. A comparison of all the thermometers is given in Table 3.

**BP APPARATUS (SPHYGMOMANOMETER)**

**Mercury sphygmomanometer**: The traditional method of measuring BP for decades, is now

<table>
<thead>
<tr>
<th>Table 3. Comparison of thermometers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parameters</strong></td>
</tr>
<tr>
<td>Mode operation</td>
</tr>
<tr>
<td>Indications</td>
</tr>
<tr>
<td>Advantages</td>
</tr>
<tr>
<td>Disadvantages</td>
</tr>
<tr>
<td>Cost</td>
</tr>
<tr>
<td>Brands</td>
</tr>
<tr>
<td>Spare accessories</td>
</tr>
<tr>
<td>Cleaning</td>
</tr>
<tr>
<td>New developments</td>
</tr>
<tr>
<td>Observer error</td>
</tr>
<tr>
<td>Reliability</td>
</tr>
</tbody>
</table>
replaced by other techniques due to environmental concerns. The BP apparatus consists of the mercury manometer, the inflatable cuff and the rubber bulb. The lever at the lower end of the manometer is turned to the on-position. The appropriate cuff (For newborn 2.5 cms, one month to 2 years 5 cms, 2 to 8 years 9 cms and for 8 years and above 12 cms) is tied to the arm of the child so as to cover half to 2/3 of arm length and making sure that the bladder encircles the arm completely. The cuff is inflated initially to find the approximate systolic value by digital palpation. Later the cuff is inflated to at least 20 mm above the systolic value and the brachial artery auscultated in the region of the elbow using the bell of the stethoscope. The appearance and disappearance of the sounds (Korotkoff) are taken as systolic and diastolic respectively. For young children, it is often necessary to allow them to play with the detached cuff and air pump before applying the cuff on the arm to gain their cooperation.

In case of difficulty in hearing Korotkoff sounds or palpating the arteries as often happens in infants and young children, a rough estimate can be made by the flushing technique. In this manoeuvre, the limb is elevated and tightly wrapped and the cuff applied to the thigh or arm in the elevated position. The cuff is then inflated to a level above the suspected blood pressure, then the arm is lowered. The cuff is slowly deflated and first flushing represents slightly below systolic pressure.

**Digital BP apparatus**

Uses ultrasonic energy beamed from a transducer to the blood vessel and recording the systolic and diastolic pressures corresponding the first and fifth Korotkoff sounds. There are automatic inflation, deflation and exhaust facilities available (Fig.6). The machine comes with standard adult size cuffs, while pediatric cuffs can be ordered separately. There is no need to use a stethoscope and this is of great use in young children who are frightened of any instrument. However the measurements often vary with every reading, so much so, that it is very difficult to get even an approximate value, especially in young children! Studies comparing digital oscillometric device with standard BP apparatus showed it to be reliable in normotensive adolescents. A comparison of various types of BP apparatus is given in Table 4.

As a part of Bogalusa Heart Study in school children using automatic device, arm blood pressure recordings were significantly different from standard BP apparatus. Digital recording using wrist worn BP apparatus were found to be not reliable (Fig.7).
Points to Remember

- Digital weighing machines are convenient and accurate for all ages.
- Stadiometer should be used for accurate height measurement
- Tympanic infrared thermometers are convenient and the readings approximate core temperatures.
- The standard mercury sphygmomanometer is still the most accurate method of measuring blood pressure

References


---

**NEWS & NOTES**

**IAP-IJPP CME 2008**

Organized by

Indian Academy of Pediatrics (IAP)

and

Indian Journal of Practical Pediatrics (IJPP)

At

Kamarajar Arangam, 492, Anna Salai, Teynapet, Chennai -600 006

Chennai

On 15th June 2008

Delegate fee:

Upto 31st May, 2008 Rs.300/- for Post Graduates, Rs. 500/- for others.

From 1st June, 2008 and spot registration Rs.750/- (as Cash/ Cheque /DD drawn in favour of “IAP-IJPP CME 2008”, payable at Chennai, Rs. 25/- for outstation cheque).

For further details contact

Dr.K.Nedunchelian and Dr. S. Thangavelu

Organising Secretaries, IAP-IJPP CME 2008

1A, Block II, Krsna Apartments,

50, Halls Road, Egmore,

Chennai – 600 008, India.

Phone: 044-28190032, 42052900

E-mail: ijpp_iap@rediffmail.com
Abstract: Drug delivery devices are instruments used for giving various types of medications and fluids to an unstable child. The available devices include infusion and syringe pumps, central venous catheters, peripherally inserted central catheters and intra-osseous needles, etc. This article deals with the details of the commonly used drug delivery devices.

Keywords: Infusion pump, Syringe pump, Central catheters.

The term “Drug Delivery Devices” refers to various kinds of medical equipment that are used for the purpose of giving different types of medications or fluids to patients. The last decade has seen an exponential increase in the availability of such equipment in India. Now clinicians are faced with a large, often confusing, choice of devices of different costs and capabilities. Information provided by the vendor is not always reliable, since they have an obvious vested interest in selling the product. The purpose of this article is to discuss the fundamentals of various commonly used devices so that the reader is better equipped to make an educated choice before the final purchase.

INFUSION AND SYRINGE PUMPS

The use of pumps to deliver fluids and medications in pediatrics is now no longer a luxury but a necessity. A wide variety of models are available in the Indian market. The indications for using these devices include delivering small volumes of fluids accurately, administering vasoactive and other drugs either continuously or intermittently, and maintain the patency of central venous and arterial catheters.

There are two basic types of pumps – volumetric infusion pumps and syringe pumps.

Volumetric pumps

Used for infusing large volumes of fluids from a bag or bottle of intravenous fluid. Most of these use a peristaltic mechanism, whereby fluid is pumped by a series of rollers that sequentially compress the intravenous tubing – because this results in fluid being delivered in mini boluses rather than continuously, they should not be used for administering vasoactive agents. Volumetric pumps usually deliver fluids at rates from 0.1 ml/hr to 999 ml/hr.

Syringe pumps

Used for precisely delivering small volumes of drugs from a syringe. They are used extensively to deliver continuous or intermittent infusion of drugs, including vasoactive agents.

Both volumetric and syringe pumps can vary greatly in their accuracy. As a general rule of thumb, the accepted error margin for volumetric pumps is ± 10%. The accuracy depends on the
type of IV tubing used – accuracy is poor with inferior quality IV tubing because of variations in the bore of the tubing. Often, the manufacturer will guarantee accuracy only if the pump is used with a specific brand of tubing – therefore, the pump must be evaluated for accuracy with a range of i.v. tubings before purchase. Various safety features, such as alarms, air detection systems, and the facility to prevent “runaway infusions” are available and essential.

With a syringe pump, one must ensure that the pump is compatible and accurate with a variety of syringes available locally. Other factors to be considered include the availability of a battery back up so that infusions can be continued during power failure or while transporting the patient. A very useful feature in syringe pumps is the ability to administer bolus doses directly, without having to reset the flow rate. Multichannel pumps that can accommodate more than one infusion are available, but are more expensive. A number of indigenous volumetric pumps are now available, often at prices far cheaper than imported ones. All pumps must be tested before purchase to ensure accuracy and ease of use. In addition, adequate after sales service is essential. It is often useful to speak with existing users before finalizing purchase.

In some situations, where accuracy is not as essential, various mechanical fluid rate controllers are available. These are attached in line and can be used for larger patients to deliver fluids. Before use, the accuracy must be tested.

**CENTRAL VENOUS CATHETERS**

Central Venous Catheters (CVC’s) are used widely in pediatrics. There are three basic types of CVC’s – percutaneously inserted CVC’s for temporary use, Peripherally Inserted Central Catheters (PICC lines) and surgically implanted long-term CVC’s (Broviac or Hickman lines). The last category is not used as commonly as the others and will not be discussed here.

**Indications for CVC’s**

Indications for CVC’s are securing venous access in seriously ill children, administration of agents such as vasoactive medications, chemotherapy or hyperosmolar drugs, parenteral nutrition, measurement of central venous pressure, and frequent blood sampling when arterial access is not possible.

The commonest types of CVC’s are those inserted percutaneously at the bedside into a large central vein – the site depends on the preferences and expertise of the operator. Of the three common sites (femoral, subclavian and internal jugular), the femoral vein is generally used more often in children due to the relative ease of insertion and safety. Unlike adults, in children this site has not been shown to have a higher incidence of complications related to sepsis.

**Size**

CVC’s are available in various gauges, lengths and lumens. The choice depends on the indication and age of the patient. In general, 4 to 5.5 French 2 or 3 lumen CVC’s are used in children. The length depends on the site, with shorter sizes reserved for the neck – one company manufactures a long (30 cm) catheter that can be inserted via the femoral vein into a supra-diaphragmatic location for monitoring CVP in children.

The choice of a CVC depends on the availability of an appropriate pediatric size and the ease of use. Various manufacturers market pediatric CVC’s in India and prices range from Rs.500 to Rs.2,500, depending on the catheter and the company.

**Complications**

CVC’s can have significant complications. Non-infectious complications include hemorrhage, pneumothorax, air-embolism and venous thrombosis. There is a significant increase in the incidence of infections attributed
to CVC’s – these infections, referred to as Catheter Associated and Catheter Related Blood Stream Infections (CABSI, CRBSI), are the significant factors that limit the use of CVC’s. The following section will briefly discuss various aspects of infection prevention. For a more detailed discussion, the reader is referred to excellent guidelines published by the Centers for Disease Control and the Indian Society of Critical Care Medicine. Strict implementation of these guidelines has been shown to decrease the rate of CRBSI significantly.

**Insertion and Maintenance of CVC’s**

Catheters should be inserted with maximal sterile barrier precautions (including cap, mask, large sterile drapes, sterile full sleeved gown and gloves). The site should be prepared with chlorhexidene (0.5 – 2%) in alcohol. If chlorhexidene based skin preparation is not available, 10% povidone-iodine solution can be used – please note that most commonly available povidone-iodine solutions are 5% concentration and are not recommended. The insertion site may be dressed with either sterile gauze or sterile transparent semi-permeable dressing. No topical antibiotic preparation is required. Complete asepsis should be used when handling the CVC and its attachments, including the use of optimal hand hygiene precautions. Intravenous administration sets may be kept for 96 hours before being replaced, unless they are used for giving blood products or lipid preparations. Disposable pressure transducers are preferred and the entire assembly should be replaced every 96 hours. There is no role for giving antibiotics either before insertion or while a CVC is in place. CVC’s need not be replaced routinely to prevent infection and should not be exchanged over a guidewire if infection is suspected. CVC’s are strictly single use and not be reused after sterilization. Antibiotic coated CVC’s are available, but mostly in the adult sizes and are more expensive. The use of these catheters is no substitute for strict adherence to catheter insertion and maintenance guidelines.

**PERIPHERALLY INSERTED CENTRAL CATHETERS (PICC LINES)**

These are long catheters inserted via a peripheral vein and threaded into the central circulation. They can be used for administering TPN, chemotherapy or other drugs safely into the central circulation and can generally be left in place longer than ordinary CVC’s. The insertion technique requires a special needle that is supplied with the kit and is easy to learn. Various sizes are available, for both neonates and older children. Since the catheters are very thin, it is usually not possible to draw blood samples from it. In addition, the catheter can easily become occluded due to a clot and therefore must be maintained carefully. PICC lines carry the same infectious risks as CVC’s. If maintained properly, they can be used for several weeks. PICC lines cost between Rs.1,000 to Rs.3,000.

**NEEDLELESS ACCESS DEVICES**

These are caps inserted onto the injection ports of CVC’s or three-way stopcocks (Fig.1). They allow a syringe to be inserted directly through the sealed cap without using a needle. Intravenous extension tubing can also be connected directly through the device. The main advantage is that one need not disconnect the cap covering the injection port, thus minimizing chances for contamination. The membrane covering the device must be wiped with alcohol

![Fig.1. Needleless access devices](image)
before use. Depending on the individual product, the connector can be left in place for as long as a week before being replaced. A number of devices are available in India, such as the Bionector® (Vygon) and the Clave Connector® (ICU Medical Inc.), and range in price from Rs.55 – 75 each. Similar devices are also available for accessing medication vials or for converting a single injection port into 2 or 3 lumens extensions (Octopus extension).

INTRA-OSSEOUS NEEDLE

Intraosseous needle placement is a lifesaving technique used when it is not possible to achieve intravenous cannulation rapidly. It is indicated in situations where patients require infusion of fluids and/or medicines rapidly, such as hypovolemic shock. The needle is inserted into the marrow cavity, usually on the medial surface of the tibia just below the tibial tuberosity using a drilling motion (Fig. 2). Insertion is easy to learn and the rate of complications low. A standard Jamshidi bone marrow needle (size 14 or 16) can be used after sterilization. Specialized intraosseous needles are also available, both of Indian origin and imported. These are easier to use than an ordinary bone marrow needle, but more expensive. An automatic battery operated bone marrow needle insertion device (EZ-IO) is available and is expected to be marketed in India shortly.

BACTERIAL FILTERS

Intravenous infusion therapy is associated with risk of contamination with bacteria, endotoxins and particulates. Infection can originate from catheter tubing, ports, cannula site or contaminated infusion fluid leading to production of endotoxin and septicemia. Certain types of fluids like total parenteral nutrition and dextrose carry higher risk. Studies have found contamination of fluid with particulate matter like rubber, crystals, fungal spores, starch, drug precipitates, and glass fragments from the opening of glass ampoules.

In-line filters reduce the risk of thrombophlebitis related to intravenous therapy. There are claims that in-line filters are effective in removing bacteria, endotoxin and particulates. There are two main filter pore sizes - the 0.22 micron filter is used for aqueous solutions whereas the 1.2 micron filter is recommended for larger molecular weight solutions like lipids. The 0.22 micron filter has been reported to remove air, microorganisms and particulate matter.

Several authors have challenged the benefits of using IV filters. The Centers for Disease Control and Prevention recommends the filtration of fluids at the time of manufacture as a cost-effective and practical way to remove particulates. It has been reported that filters can retain some drugs, including antibiotics, thereby reducing their efficacy. Blocked filters need to be replaced, thus increasing the cost and the risk of introducing infection while changing it. Most importantly, filters do not reduce the risk of contamination entering the line below the level

![Fig. 2. Intra-osseous Needle](Reproduced from “Intraosseous Infusions” in Essentials of Pediatric Intensive Care, 2nd edition. Levin DL, Morriss FC (ed). Churchill Livingstone 1997)
of filter. The use of inline filters is not a substitute for improper aseptic precautions.

A recent Cochrane systematic review of the use of intravenous in-line filters in neonates found no significant difference in the final outcome. Currently, the use of in-line filters to reduce the risk of catheter related infection is not recommended.

**NEEDLE AND SYRINGE DESTROYERS**

These devices are intended to permanently destroy disposable needles and syringes to prevent accidental or intentional reuse. The needle is usually destroyed electrically and the syringe cut manually. Many different models are available in the market. However, most of these devices are problematic in that they take quite some time to use and the cutting blade becomes dull rapidly. Some also generate a bad smell and smoke when the needle is electrically burnt. Because of these issues, many devices are purchased but not used. Before deciding on a suitable device, it is important to discuss it with current users and also to try out a demonstration piece to ensure satisfactory performance.

**Points to Remember**

- *Infusion and syringe pumps deliver accurate fluid volume.*
- **Central catheters and peripherally inserted catheters are very useful to deliver fluid, drugs and nutrition in seriously ill children.**
- **Intra-osseous needle placement serves as a life saving measure to deliver fluids in hypovolemic shock.**

**References**


**NEWS & NOTES**

3rd World Congress of Pediatrics, Gastroenterology, Hepatology and Nutrition

at

Igassu Falls, Brazil

16th to 20th August, 2008

Contact :

http://www.fispghan.org
PULMONARY DEVICES IN OFFICE PRACTICE

* Nagabhushana S

Abstract: Pulmonary devices in office practice include equipment not only to deliver inhalational medicines and monitor the course/improvement but also to diagnose respiratory problems. They include metered dose inhaler with spacer, rotacap, nebuliser and peak flow meter. This article deals with the commonly used pulmonary devices.

Keywords: Peak flow meter, Metered dose inhaler, Nebuliser

Pulmonary devices are equipments used either in the diagnosis or management of respiratory problems in children. Peak flow meter, incentive spirometry device, spirometer, etc., aid in diagnosis, while inhalation therapy equipment, devices used in chest physiotherapy, cough assist device, CPAP/BIPAP, etc. are useful in therapeutics. This article attempts to describe the uses of commonly used equipment in office practice.

PEAK FLOW METERS (PFM)

PFM’s are handy instruments useful in office practice as well as for home monitoring of lung functions. They usually document the changes of forced expiratory flow through medium and large airways. They are usually available in two ranges: low range (<350L) for use in younger children and high range (<800L) for use in older age groups. Children above the age of five years can be taught to use them. The areas of utility of PFM are 1) Early recognition of an impending attack of asthma, 2) Documenting deterioration of lung function following trigger exposure, 3) Response to therapy following an acute attack, 4) Documenting exercise induced dips by serial monitoring, 5) Documenting nocturnal/early morning dips in a child who is ‘well’ during the day, 6) Long term monitoring of chronic asthma, 7) Home management of early asthma attacks, 8) Child with ‘Difficult to control’ asthma, 9) Child who is noncompliant to therapy in addition to consideration of all other factors, 10) Adolescent with uncontrolled asthma, when PFR improvements serve as a positive reinforcement and vice versa and 11) Research purposes.

How to use the PFM?

1) Fix the clean mouth piece to the meter, 2) Bring the pointer to zero, 3) Let the child stand up and hold the peak flow meter horizontally without restricting the movement of the pointer, 4) Place the mouth piece in the child’s mouth and let him purse his lips snugly around the mouth piece, 5) Instruct the child to breathe in as deep as possible. Let him blow out as hard and as fast as possible, 6) Record the values and consider the best of three readings.

The concept of personal best (PB)

The best peakflow recordings of any child are usually in the evenings. This individualized best is obtained by computing the recordings over
2-3 weeks. Personal best is taken as the baseline reference point for that child. In the absence of personal best values, the formula of 100 cms = 100 litres with increments of 50 liters for every 10 cm height can be used. The percentage reduction in peak flow values during exacerbations is in relation to this value.

**Diagnosis**

An improvement of 60L/min (or more than 20% of pre bronchodilator PEF) after inhalation of bronchodilator, or diurnal variation of more than 20%(with twice daily recordings, more than 10%) suggests a diagnosis of asthma. The concept of different zones as described below indicates the level of control and the necessary steps to be adopted.

**Patient (parent) education point**

**Green Zone:** 80 to 100 percent of “normal” peak flow rate signals “all clear” A reading in this zone means that asthma is under reasonably good control. It would be advisable to continue prescribed program of management.

**Yellow Zone:** 50 to 80 percent of usual or “normal” peak flow rate signals “caution”. It is a time for decision. The airways are narrowing and may require extra treatment. Symptoms can get better or worse depending on actions taken as prescribed and early evaluation by his doctor.

**Red Zone:** Less than 50 percent of usual or “normal” peak flow rate signals a ”Medical Alert”. Immediate actions need to be taken. Severe airway narrowing may be occurring and rescue medications are to be taken right away. Parents have to contact doctor immediately and follow the plan he has given for red zone readings.

**Advantages**

PFM provides objective assessment in office practice. Improvement in peak flow values with time while on regular inhaled medications serves as a positive reinforcement to the child and his family. Sudden dips in peak flow values can convince the parents of the defaulting child to be compliant to long term controller use.

**Limitations of the peakflow meter**

1) It cannot be used in children below five years of age. 2) It does not adequately document changes in small airway caliber. 3) It may record normal values for age in between acute episodes and 4) It is user and technique dependent. Wrong technique, particularly in adolescence, can yield spurious values.

**Calibration**

All PFM’s have to be periodically calibrated in order to maintain accuracy by the manufacturer. A peak flow meter used for some time may be compared with a new instrument to grossly check its accuracy.

**INHALATION THERAPY DEVICES**

Inhaled remedies have been used for centuries in the treatment of respiratory disorders. They are the mainstay of management of asthma both during acute exacerbations and for long term management. Relevant details about their optimal use and maintenance is described.

Successful inhalation therapy is dependent on the availability of adequate quantity of respirable particles in the mixture (2-5 microns). Particles above this size get deposited mostly in the upper airways and those that are small, tend to get deposited in the alveoli or show Brownian motion.

**Nebulisers**

These are active devices for passive patients. They are useful in managing asthma in acute settings when the child will not be able to inhale at will. They are, however, not recommended
for home use. They are available as (a) Jet nebulisers (Fig.1a), which are commonly used (piston driven-durable and diaphragm driven-less durable and more noise producing) and (b) Ultrasonic nebulisers-expensive option (Fig.1b).

**Advantages:** 1) The child’s co-ordination is unnecessary, 2) It can be administered to a child who is ventilated and 3) Continuous/back to back nebulisations are effective in managing severe episodes.

**Disadvantages:** 1) An infant who cries excessively while being nebulised stands to get less medication as he exhales more than he inhales. It is therefore useful to keep the infant as calm as possible, in his mother’s lap, and reduce the sounds of the nebuliser to the minimum. 2) An ill fitting facemask can cause significant loss of medication. A face mask held only 2 cm away from the face may reduce the drug delivery by 85%. 3) Other disadvantages include the relative high cost, time spent and supervision during the administration, etc.

**Practice point - Jet nebulisers:** Always use saline and not water as vehicle. Water can cause reflex bronchospasm as it alters the pH of the bronchial mucosa. Salbutamol/Terbutaline can be combined with Ipratropium. Inhaled steroids have to be nebulised alone. Intermittent nebulisation while inhaling alone (which is possible by occluding a vent provided around the nebulising chamber) yields better drug deposition. Children above six years can be encouraged to inhale using the mouth piece. It is prudent to nebulise with oxygen at least during the first golden hour of acute attack. Use the appropriate fill in volume (at least 3-5 ml) and nebulise at least for five minutes. There will be a spluttering sound towards the end of nebulisation, when gently but frequently tapping the walls of the nebuliser helps to increase the volume output. Nebulisation can continue for a minute after the spluttering occurs.

Whenever possible, children should be encouraged to breathe through the mouth. If old enough, they should use a mouth piece rather than a facemask.

**Maintenance:** The tubing and the chamber have to be cleansed with soap and water after each nebulisation and empty run at least for a minute. At the end of the day’s use, they can be dipped in a solution of soap and water and cleansed thoroughly. Alternately, they can be dipped in
a solution of white vinegar 1:3 dilution for 10 minutes and thoroughly washed under a forceful jet of running warm water, dried and preserved in a clean place. If the nebuliser is not used for a long period, the components have to be kept in a clean plastic cover.

The tubing of the nebuliser gradually gets discolored and turns hard with use. It is then time to change them. As a rule of thumb, the nebuliser tubing has to be changed once in at least six months, or even early if used very frequently.

Those who can afford the cost (around one hundred rupees for individual use), can have a nebuliser unit to be used for their child only to avoid possibility of cross infection. Sets that are frequently used cost rupees four hundred only. E.g. for institutional or hospital use. The nebuliser filter gets discolored with use and it has to be periodically changed. The most important part of the jet nebuliser is the baffle, which has to be preserved carefully after washing. Compressors should be serviced regularly, at least annually. The degree of drug deposition is only 1-5%. Considering the profile of drug deposition in the airways, as benchmark of successful inhalation therapy, nebulisers are an inferior choice.

**Ultrasonic nebuliser:** Has an electrically powered transducer which produces sound energy. This sound energy causes fluid particles to be torn away from the surface of the liquid.

**Advantages:**
1) It produces better relative humidity (almost 100%), and a dense stable mist and
2) Sterilisation of the equipment is easy.

**Disadvantages:**
1) It can cause over hydration of the airways and focal atelectasis, 2) induce excessive cough which can, however, be overcome by using supplemental oxygen and 3) induce breathlessness which can be minimized by reducing the volume of the mist or changing the solution.

**Which nebuliser to buy?**

Piston (particularly metal) driven jet nebulisers are always better than the diaphragm driven ones.

Please look out for these details: 1) The respirable particle size of 2-5 microns. They should provide a respirable fraction of at least 50% at their recommended driving gas flows, 2) the fill in volume (up to 6 ml), 3) the nebulisation time (usually less than 10 minutes), 4) the availability of backup and maintenance after sales services, 5) feasibility of field testing the respirable particle size, periodically, even at extra cost, 6) availability of an oxygen port, 7) reasonable cost. Jet nebulisers with durable pistons and capacity to nebulise for longer time tend to cost more e.g. Pulmo aid, while basic models of ultrasonic nebulisers cost around twelve thousand rupees.

**Pressurised metered dose inhalers (pMDI)**

They are versatile and popular devices useful in almost all settings. The parts of a pMDI are shown in Fig.2.

In clinical practice, pMDI should always be used with a spacer device (Fig.3). The advantages of using a spacer are: 1) Avoids hand lung co ordination which is crucial in determining the percentage of drug deposition in the airways, 2) Higher deposition of the drug as more drug is

---

**Fig. 2. Metered dose inhaler**
available in the spacer to be inhaled in 3-4 breaths. 3) avoids the ‘cold Freon effect’ i.e., sudden cooling of the posterior pharynx due to rapid expansion of the propellant, which makes the child to reflexly exhale rather than inhale and 4) non respirable particles mostly stay within the spacer- a major advantage while using inhaled steroids which avoids oral candidiasis.

Spacers, however do not decrease the amount of drug deposited in the larynx and do not protect against dysphonia, a common local side effect of inhaled corticosteroids (ICS).

Spacers are available in the following formats: 1) Large volume (750 ml, useful in older children) and small volume (250 ml useful in infants and toddlers), 2) electrostatic (Polycarbonate, transparent) and non electrostatic (Polyamide, nontransparent) spacers, 3) valved and nonvalved spacers, 4) commercially available and home made (a mineral water bottle of at least 750 ml).

Studies in India and abroad have shown that home made spacers serve as cheaper yet reasonably efficient devices wherein economic constraints exist. The dictum today, therefore, is “use any spacer but use a spacer along with pMDI.

“Practice tips”: Make the spacer attractive and acceptable. Allow the child to play with the spacer and/or baby mask initially and then help him to learn to inhale through the spacer, asking him to simulate the demonstration, initially only with the face mask, then the spacer and finally the pMDI in that order. Instruct parents to stick colorful labels, stickers on the spacer to make it attractive, help the child to own his spacer.

Cleansing: Clean once a month with detergent and water and usually drip dried. Change your spacer once in 6 months or even earlier if damaged/broken. The canister of a full pMDI sinks in a mug of water. A completely empty canister floats on water. It is prudent to keep a ‘puff count’ as once the canister is around 80% empty, the drug delivery is not optimal. It is then time to change over to a new canister.

Utility: Useful both for long term (with ICS) and short term use (β₂ agonists). pMDI with spacers can be effectively used to manage acute attacks at home and on the way to hospital as well as in the emergency and ward setting and also during acute severe exacerbations in the absence of a nebuliser. pMDI with spacer use is likely to cause less side effects when compared to nebuliser during acute episode management.
Drug delivery from a DPI depends entirely upon child’s inspiratory effort and are generally easy to use in older children. The inhaled medicine is mixed with an inert carrier substance (generally lactose) and presented in a gelatin capsule. The contents of the capsule are inhaled through rotahaler which opens the gelatin capsule (Fig. 4). The child inhales the medication through the vents. They are generally useful in children above five years of age. As they can be bought at smaller aliquots, these devices are popular with patients who have economic constraints. Further, the taste and sensation of lactose inside the mouth, as well as the visual effect of the drug clearing from the capsule induces patient satisfaction.

**Disadvantages:** The powder inside the capsule crystallizes on accidental exposure to moisture. The device may not be able to open the capsule at times. When it occurs, either a new capsule or a new device respectively may be needed depending on the situation.

Multihaler, Accuhaler and Novoliser are devices which have multiple doses of medications and are handy. Turbohaler, a device which spins the medication on delivery, is noted to improve lung drug deposition by two times compared to the rest. This aspect has to be remembered when changing from this device to another device or vice versa.

The child should rinse and gargle mouth soon after DPI use, which will decrease the systemic side effects from drug deposition in the oropharynx. Younger children may be helped to brush teeth and gargle mouth soon after inhalation. However, the incidence of dysphonia does not decrease with this act.

**Practice point:** A knowledgeable physician with a compassionate heart, who has adequate time for the child and his parents during every visit, is the key to successful inhalation therapy. During the initial visit, appropriate explanation and demonstration regarding the use of the device and reinforcing this knowledge during subsequent visits is absolutely necessary. It is prudent to hand over written individualized plans for device use.

**Points to Remember**

- *pMDI and rotacaps are very useful pulmonary devices for drug delivery in asthma.*
- *Nebulisers are useful for drug delivery in acute care settings.*
- *Proper usage gives very satisfying control of disease.*
Bibliography


NEWS & NOTES

13th INTERNATIONAL CONGRESS OF INFECTIOUS DISEASES
at
Kuala Lumpur, Malaysia
19th to 22nd, June, 2008

Contact
International Society for infectious Diseases
1330, Beacon Street, Suite 228,
Brookline,
Massachusetts,
02446-3202 USA
Info@isid.org
http://www.isid.org
LIFE SUPPORT EQUIPMENTS

* Anand K Shandilya
* Surpreet Nagi

Abstract: Life support equipments are required in an emergency and it is important always to have them ready for instant use. This article discusses equipment for establishing and maintaining the airway and breathing, as well as oxygen delivery devices. Oxygen delivery systems can be broadly divided into low flow and high flow systems. High flow systems can reliably deliver oxygen irrespective of the patient’s minute ventilation. Oxygen masks like a simple facemask, partial rebreathing and non rebreathing masks, venturi devices, oxygen hoods, self inflating bags and ventilation masks, flow inflating bags, tracheal tubes and laryngeal mask airways are discussed in detail.

Key words: Life support equipments, Air way, Breathing, Oxygen delivery devices.

Life support equipments are required in an emergency. It is very important to keep them ready for immediate use at any time. The staff in charge of all emergency departments, ICU and operation theatres should check and make sure that all the equipments are functional and readily available.

VENTILATION MASKS

The mask consists of a rubber or plastic body, a rim or face cuff or seal, and a standard adapter to connect a bag or a ventilation circuit. Ideally the mask should be transparent, permitting the rescuer to observe the color of the child’s lips and condensation on the mask (indicating exhalation) and to detect regurgitation (Fig.1a). The mask should provide an airtight seal. The mask should extend from the bridge of the nose to the cleft of the chin, covering both the nose and the mouth but avoiding compression of the eyes (Fig.1b). Soft circular masks with cushioned rim are preferred as they can form an effective seal and are less likely to leak or cause damage to the infant’s eyes. In infants and toddlers the under mask volume should be as low as possible in order to decrease the dead space and to prevent rebreathing of exhaled gasses.

RESUSCITATION BAGS

In most emergencies where assisted ventilation is required, effective bag mask ventilation will provide adequate oxygenation and ventilation until control of airway can be achieved. All health care providers who care for infants and children should be trained in effective bag mask ventilation.

---

* Dr. Anand’s Hospital for Children, Jogeshwari East, Mumbai - 400 060
Resuscitation bags are used to provide ventilation to patients who have inadequate ventilation despite a patent airway. There are two types of resuscitation bags: self inflating and flow inflating.

**Self inflating bag**

A self inflating bag with a face mask provides a rapid means of ventilation in an emergency and does not require an oxygen source for inflation. The bag recoil mechanism fills the bag from a gas source or from room air (Fig.2). During bag reinflation, the gas inlet valve opens and oxygen is drawn into the bag. During bag compression the gas inlet valve closes and a second fish mouth valve opens to permit gas flow to the patient. During exhalation, the bag outlet valve (one way, non rebreathing) closes and the exhaled air is vented to the atmosphere to prevent rebreathing of carbon dioxide. A self inflating bag delivers room air (21% oxygen) unless supplemental oxygen is provided. An oxygen reservoir is used to deliver a consistently high oxygen concentration (60-95%). A minimum oxygen inflow rate of 10-15 l/min is required to maintain adequate oxygen volume in the reservoir. The concentration of oxygen delivered is considerably lower if a reservoir is not used. Many self inflating bags are equipped with a pressure limited pop off valve set at 35-45 cm of water to prevent barotrauma. During resuscitation if higher pressures are required, the pop off valve may need to be manually occluded. Ideally bags used for resuscitation should have no pop-off valve or one that is easily occluded. As this bag has a fish mouth non re-breathing outlet valve, it cannot be used to provide oxygen to a spontaneously breathing child. The bags made of siliconized rubber can be autoclaved. These bags are superior to the plain rubber bags. The bag should be appropriate for the child’s size, so that the operator has a “feel” for the patient’s lung compliance. A sudden decrease in the lung compliance (resistance) could be due to airway obstruction, over distention of the lungs (due to excessive inflating pressures, high PEEP or high ventilation rates), or a pneumothorax.

**Flow inflating/Anesthesia bags**

These bags require a flow of gas to operate. They are used in inpatient settings such as the ICU or the operating room. They are also referred to as “Anesthesia” bags. Safe and effective ventilation with these bags requires more skill than with the self inflating bags. The bag consists of a reservoir bag, an overflow port, a fresh gas inflow port, and a standard connector for mask/tracheal tube connection(Fig.3). The only valve in this system is the expiratory or pressure relief valve, which has to be adjusted to maintain gas volume in the bag to maintain appropriate positive pressure and allow an oxygen inflow sufficient to wash out exhaled air. The bag remains collapsed when not in use. It gets inflated only when air/oxygen is forced into it and is thus dependent on a compressed gas source. The composition of inspired gas is determined by the rate of fresh gas flow. To achieve ventilation the provider must be able to adjust the flow of fresh gas, adjust the outlet control valve, and ensure proper seal with the face mask. If the pressure valve offers too much resistance to the out flow of gas, then the bag becomes too distended and produces high airway pressure with the potential
for barotrauma, impedance to the venous return and hypotension. If the bag refills slowly then the rate of ventilation is limited or the tidal volume is too low. If the pressure relief valve is opened too much, gases will escape from the bag too quickly and the bag will collapse when compressed leading to ineffective ventilation and/or low tidal volume. The volume of the reservoir bags ranges from 500 ml for infants, 600-1000 ml for children and 1500-2000 ml for adults.

Flow inflating bags can be used to provide supplemental oxygen during spontaneous respiration even in small infants. PEEP or CPAP may be provided through this bag by partially closing the adjustable pressure relief valve until the desired level of PEEP is achieved. The Jackson Rees Pediatric circuit is commonly used in children.

**OXYGEN CYLINDERS**

These are reusable cylinders consisting of a body, shoulder, and a valve. The valve can be a hand wheel valve or bullnosed valve. Tubing is attached to the outlet of the valve in such a way that oxygen passes through the water first and then to the main tubing and oxygen catheter. It provides humidified gas to the patient.

They are generally made of molybdenum steel. Oxygen in the cylinder is in gaseous form under pressure of 240 kg/cm². An average size cylinder weighs 15.2 kg when full and 10.2 kg when empty. The valve of the cylinder should be opened slowly and closed after using only moderate force. It can be tested with soap water for leakage. The cylinder should be kept in a cool place away from any source of heat or inflammable material.

**OXYGEN DELIVERY SYSTEMS**

Oxygen uptake and delivery are compromised during cardiac arrest and other serious illnesses, so oxygen should be administered in high concentration to all seriously ill or injured patients with respiratory insufficiency, shock or trauma, even if measured arterial oxygen tension is high.

The choice of oxygen delivery is determined by the child’s clinical status and the desired concentration of oxygen. A delivered oxygen concentration of 100% is reserved for resuscitation or transport. In other situations the concentration selected is lower. Care should be taken to humidify the oxygen. Alert children should be allowed to remain with their parents and airway equipment, including oxygen should be introduced in a non threatening manner.

Oxygen therapy refers to increasing the concentration of inspired oxygen to treat or prevent tissue or cellular hypoxia.

Oxygen is a drug and like any drug the dose and duration of therapy needs to be specified. The first thing to ensure before starting oxygen is that there is a patent airway. The devices used for delivery of oxygen can be classified into low flow, reservoir systems, high flow and enclosure devices.

**Low flow system**

Here 100 % oxygen mixes with room air during inspiration because the oxygen flow is less
than the patient’s inspiratory requirements and the mask does not fit tightly on the face. These devices deliver variable concentration of oxygen depending on the patient’s minute ventilation (variable performance oxygen delivery systems). Low flow devices like nasal prongs, nasal catheters, simple face mask are easy to use, readily available and economical. Low flow systems can provide an FiO2 of 23% to 80% though unreliably. In small infants due to low minute ventilation these systems can provide a high concentration of oxygen.

**High flow system**

The flow rate and reservoir capacity provide adequate gas flow to meet the total inspiratory requirement of the patient. These devices deliver a reliable and fixed oxygen concentration irrespective of the patient’s minute ventilation (fixed performance oxygen delivery systems). Eg Venturi, Oxygen Hood, Non-rebreathing mask, (Provided the flow rate is three times the patients minute ventilation). The best example of a high flow device is a venturi system with a mask. With this device the patient’s inspired oxygen concentration can be gradually reduced if he can maintain a stable saturation of oxygen as seen on pulse oxymetry. This device should be used as often as possible, as it helps in weaning the patient off oxygen especially in the absence of availability of blood gas analysis.

At the same time if a patient is unable to maintain saturations with a FiO2 of 0.5 (as with a venturi) one can take a decision about CPAP or ventilation.

**Reservoir systems**

Include simple face-masks, partial and non-rebreathing masks.

**Enclosure systems**

Include an oxygen tent, oxygen hood and closed incubators.

**Oxygen masks**

Several types of oxygen masks may be used to administer humidified oxygen in a wide range of concentrations.

**Simple face mask**

Simple oxygen mask is a low flow device that delivers 35-60% oxygen with a flow rate of 6-10 l/min. A face mask consists of a rubber or plastic body, a connecting port, and a rim or face seal. It is a plastic reservoir designed to fit over the patient’s nose and mouth and be secured around the patient’s head by an elastic strap (Fig.4). The mask has a reservoir volume of 100 – 200 ml. Oxygen is delivered through a small-bore tube connected to the base of the mask. Holes on each side of the mask provide an egress for exhaled gases and serve as room-air entrainment ports. Face masks are available in a variety of sizes. Simple oxygen masks are used to provide supplemental O2 in the moderate range (FiO2 0.35-0.50), depending on the size and minute ventilation, for short periods of time (eg. during procedures, for transport, in emergency situations). A minimum oxygen flow rate of 6 L/min must be used to maintain an inspired oxygen concentration and prevent rebreathing of exhaled carbon dioxide. The FiO2 varies with the patient’s inspiratory flow.
requirement. Irritation may result from tight application. Rebreathing of CO₂ may occur if total O₂ flow is inadequate. These masks interfere with feeding. They may not be available in sizes appropriate for all patients.

**Partial rebreathing mask**

A partial rebreathing mask consists of a simple face mask with a reservoir bag which has a capacity of 600–1000 ml. It provides an inspired oxygen concentration of 50-60%. During exhalation, the first third of the exhaled air flows into the reservoir bag and combines with fresh oxygen. The remaining 2/3 rd of the exhaled air escapes through the side ports. When the patient inhales next, the inspired gas comprises of the first 1/3 rd of the previous exhaled tidal volume (which is oxygen rich as it comes from the upper airway and is not involved in respiratory gas exchange during the prior breath) from the reservoir and the fresh oxygen in the bag and mask. Rebreathing of exhaled carbon dioxide from the mask is prevented if the oxygen flow rate into the bag is consistently maintained above the patient’s minute ventilation. It is important that the reservoir does not deflate completely or this would lead to entrainment of room air through the side ports and fall in FiO₂.

For this device to be effective, an oxygen flow rate of 10-12 L/min is essential to flush carbon dioxide out of the mask and keep the reservoir bag distended.

**Non rebreathing mask**

This is similar to partial rebreathing mask but does not permit the mixing of exhaled gases with the fresh gas supply. It consists of a face mask and reservoir bag with the following additions: A one way valve at the exhalation port to prevent entrainment of room air during inspiration, and a one way valve placed between the reservoir bag and the mask to prevent flow of exhaled gas into the reservoir (Fig.5). An inspired oxygen concentration of 95% can be achieved with an oxygen flow rate of 10-15 L/min. This is the ideal device to give high oxygen concentration (FiO₂ 0.6-1.0) to a spontaneously breathing child in the emergency room.

**Venturi mask**

Is a high flow system designed to provide controlled, low to moderate (25-60%) inspired oxygen concentrations. An air-entrainment mask is designed to fit over the patient’s nose and mouth and contains a short corrugated hose with

---

**Fig.5. Non rebreathing mask.**

**Fig.6. Venturi mask.**
Fig.7. Oxygen hood.

a jet orifice that is connected to oxygen supply tubing. Oxygen under pressure is forced through a small jet orifice entering the mask. The velocity increases causing a shearing effect distal to the jet orifice, which causes room air to be entrained into the mask (Fig.6). The total flow provided by the mask, is determined by the cross-sectional area of the entrainment ports, the diameter of the jet orifice, and the oxygen flow to the jet. The FiO₂ is determined by the dimensions of the jet and the entrainment ports. The entrainment mechanism is based on the principles described by Bernoulli. A collar can be attached to the base of the corrugated hose for supplemental humidification.

Oxygen hood

It is a transparent plastic shell that encompasses the patient’s head (Fig.7). A continuous flow of humidified oxygen is supplied to the hood. It allows for FiO₂ up to 95% to be administered. Minimum flow rate should be 10 L/min. The advantages of this mode of oxygen delivery are that it is well tolerated by infants, allows easy access to the chest, trunk, and extremities; and permits control of inspired oxygen concentration and humidity. However, it cannot be used in children older than 1 year of age. Prolonged exposure to humidified oxygen may increase risk for cutaneous fungal infection.

Fig.8. Nasal prongs

Inadequate or loss of gas flow may result in hypoxia or hypercapnia (due to rebreathing of exhaled air). Temperature within enclosures should be closely monitored to reduce the potential for cold stress or apnea from overheating in neonates. Use of an improperly sized hood can result in irritation of the infant’s skin.

Nasal cannula/prongs

This is a low flow oxygen delivery device meant for children who require only low levels of supplemental oxygen (Fig.8). It consists of two soft prongs that arise from the oxygen supply tubing. The prongs are inserted into the patient’s nares and the tubing is secured to the patient’s face. Oxygen flows from the cannula into the patient’s naso-pharynx which acts as an anatomic reservoir. The inspired oxygen concentration cannot be reliably determined from the nasal oxygen flow rate because inspired oxygen concentration is influenced by other factors such as, nasal or oropharyngeal resistance, inspiratory flow rate, tidal volume, and nasopharyngeal and oropharyngeal volume. A high flow rate (>4L/min) can irritate the nasopharynx. Nasal cannula does not provide humidified oxygen and may not deliver sufficient oxygen if nares are obstructed. Skin irritation can result from material used to secure the cannula or from local
Table 1. Flow rates required and FiO₂ delivered by various O₂ delivery devices

<table>
<thead>
<tr>
<th>Device</th>
<th>Flow Rate of Oxygen in L/min</th>
<th>FiO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasal Prongs/Catheter</td>
<td>Maximum 4</td>
<td>0.24-0.44 (approx 4%/litre flow)</td>
</tr>
<tr>
<td>Simple Face Mask</td>
<td>5-8</td>
<td>0.35-0.55</td>
</tr>
<tr>
<td>Partial Re-breathing Mask</td>
<td>10-12</td>
<td>0.5-0.7</td>
</tr>
<tr>
<td>Non-re-breathing</td>
<td>10-15</td>
<td>0.7-1.0</td>
</tr>
<tr>
<td>Venturi</td>
<td>Variable (see package insert of device)</td>
<td>0.24-0.5</td>
</tr>
<tr>
<td>Oxygen Hood</td>
<td>10-15</td>
<td>Up to 0.95</td>
</tr>
<tr>
<td>Anesthesia Bag</td>
<td>250 ml/kg or 3 x MV</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Fig.9a. and 9b. : Oropharyngeal and nasopharyngeal airways

allergic reaction to polyvinyl chloride. Improper sizing can lead to nasal obstruction or irritation. Displacement can lead to loss of oxygen delivery. Prongs are difficult to keep in position, particularly in small infants. Use may be limited by the presence of excessive mucus secretion, mucosal edema, or a deviated septum. Maximum flow should be limited to 2 L/min in infants and newborns. Care should be taken to keep the cannula tubing and straps away from the neck to prevent airway obstruction in infants. A summary of the oxygen delivery systems, required oxygen flow rates and the FiO₂ delivered can be seen in Table 1.

**AIRWAYS**

**Oropharyngeal airway:** This consists of a flange, a short bite-block segment, and a curved body usually made of plastic and shaped to provide an air channel and suction conduit through the mouth (Fig.9a). The curved body of the oropharyngeal airway is designed to fit over the back of the tongue to hold it away from the posterior wall of the pharynx. Airway sizes range from 4-10 cm in length. Proper size may be estimated by placing the oropharyngeal airway against the side of the face. With the flange at the corner of the child’s mouth, the tip of the airway should reach the angle of the jaw. In the unconscious child it can be used to open the airway. It should not be used in a conscious or semi-conscious patient because it may stimulate gagging and vomiting. A larger airway may obstruct the larynx or may damage the laryngeal structures. A smaller airway or improperly inserted airway pushes the tongue posteriorly and may obstruct the airway.
Nasopharyngeal airway

It is a soft rubber or plastic tube that provides a conduit for air flow between the nares and the pharynx (Fig. 9b). The proper airway length is approximated by the distance from the tip of the nose to the tragus of the ear. The catheter should be inserted into the patient’s nose to a depth equal to the distance from the ala nasi to the tragus or be gently advanced and then be withdrawn until it rests slightly above the uvula. The tube secured to the patient’s face is connected to the oxygen supply tubing. When selecting a nasopharyngeal airway care should be taken that the outer diameter should not be so large so as to cause sustained blanching of the alae nasi. Diameter ranges from 12 – 36 French. It can be used in conscious patients as well as in children with impaired consciousness or neurologically impaired children with poor pharyngeal tone or coordination. Disadvantages of the nasopharyngeal airway are that mucus, blood, vomitus or soft tissues of the pharynx can obstruct it. A longer airway may cause bradycardia through vagal stimulation, or it may injure the vocal cords or epiglottis. Irritation of the pharynx may stimulate coughing, vomiting or laryngospasm. Skin irritation may result from material used to secure the cannula or from local allergic reaction to polyvinyl chloride. Excessive oxygen flow may cause gastric distention.

TRACHEAL TUBE

The tracheal tube is a disposable tube made of translucent polyvinyl chloride with a radioopaque marker (Fig. 10). A standard 15 mm adapter is attached to the proximal end for attachment to a ventilating device. The distal end of the tube has an opening in the side wall (Murphy eye) to reduce the risk of atelectasis and complete tube obstruction if the end opening is occluded. The tube has calibrated marks used as reference points during placement. A vocal cord mark may be provided at the distal end of the tube. A stylet may be used to provide rigidity to the tracheal tube and to guide it through the vocal cords. Care should be taken that the tip of the stylet is 1-2 cm proximal to the distal end of the tracheal tube to prevent trauma to the trachea. A cuffed tracheal tube can be used in all children beyond the neonatal period. Cuffed tubes may be preferable when there is poor lung compliance (eg. Pneumonia or ARDS), high airway resistance,(eg. Status asthmaticus) or with a large glottic air leak. Care should be taken that the cuff pressure is less than 20 cm water. Correct tracheal tube size may be estimated by using age based formulas or those based on body length. In a child older than 2 years, tracheal tube size may be estimated as:

Uncuffed tracheal tube size(mm) = \( \frac{\text{Age (years)}}{4} + 4 \)

Cuffed tracheal tube size(mm) = \( \frac{\text{Age (years)}}{4} + 3 \)

The proper depth of insertion for children older than 2 years may be estimated as:

Depth of insertion(cm) = \( \frac{\text{Age (Years)}}{2} + 12 \)

Alternatively, the distance of insertion from the distal end of the tube to the lip can be estimated:
by multiplying the internal diameter of the tube by 3.

Tracheal intubation is indicated in respiratory insufficiency, prolonged mechanical ventilation, airway obstruction, loss of protective airway reflexes, and impaired CNS control of ventilation.

**LARYNGOSCOPE**

The laryngoscope consists of a handle with a battery and a blade with a light source. This is a instrument to be used by left hand for both right and left handed persons. The blade may be straight or curved. Straight blade is preferred for infants for better visualization of the glottis which is more cephalad in infants as compared to older children. A curved blade is preferred for older children because its broader base and flange facilitates displacement of the tongue and improves visualization of the glottis.

Insertion of the laryngoscope: Hold the laryngoscope handle in your left hand and insert the blade into the right side of the mouth, displacing the tongue to the left. Follow the natural contour of the pharynx to the base of the tongue. Position the tip of the blade in the vallecula. Visualize the epiglottis. The larynx is visualized with a straight blade by lifting the mandible with the blade in the direction of the long axis of the laryngoscope handle. If the glottis is not visible, use the tip of the blade to lift the epiglottis. With the curved blade you insert the tip into the vallecula to displace the tongue anteriorly. After the blade is properly positioned exert traction upward in the direction of the long axis of the handle to displace the base of the tongue and the epiglottis anteriorly, exposing the glottis. The blade should not be inserted into the esophagus and then withdrawn to visualize the glottis, as this increases the risk of laryngeal trauma. The handle and blade should not be used for prying and levering. The upper gums or teeth should not be used as a fulcrum.

**LARYNGEAL MASK AIRWAY**

It is a reusable device made of medical grade silicon rubber. It consists of a tube with a cuff, mask like projection at the distal end and a mask inflation line (Fig.11). LMA is introduced in the pharynx and advanced until resistance is felt as the tube enters the hypopharynx. The balloon cuff is then inflated which seals the hypopharynx, leaving the distal opening of the tube just above the glottic opening and providing an airway. It is available in a range of sizes.

**LMA size selection guidelines:**

<table>
<thead>
<tr>
<th>Size</th>
<th>Patient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Upto 5 kg</td>
</tr>
<tr>
<td>1.5</td>
<td>5 – 10 kg</td>
</tr>
<tr>
<td>2.0</td>
<td>10 – 20 kg</td>
</tr>
<tr>
<td>2.5</td>
<td>20 – 30 kg</td>
</tr>
<tr>
<td>3.0</td>
<td>30 – 50 kg</td>
</tr>
</tbody>
</table>

LMAs are indicated in elective surgical procedures where face masks are currently used or tracheal intubation is not necessary. Can also be used when tracheal intubation is precluded by lack of available expertise or equipment, or when attempts at tracheal intubation have failed. LMAs are contraindicated in a child with an intact gag reflex. It may be more difficult to maintain than a tracheal tube during transport. They are relatively more expensive than tracheal tubes, although they can be reused.
Points to Remember

- Knowledge on equipments for maintaining the airway and support breathing is needed.
- Proper attention to maintaining the equipment and being prepared at all times is essential.

Bibliography


NEWS & NOTES

NARAYANA MEDICAL COLLEGE & HOSPITAL
CHINTHA REDDY PALEM, NELLORE 524002, ANDHRA PRADESH
Phones 0861-2317963/64/68 Fax 0861-2331763(Hosp)/2317962(Coll)/2308385(Coll Acc Sec)

Postgraduate Department of Pediatrics
Dr. Suraj Gupte, MD, FIAP Mobile Phone 94904 92804
Professor & Head E-mail:surajgupte@rediffmail.com

Pediatric Advanced Life Support (PALS) Course
(Latest IAP/AHA/AAP Guidelines)
Under the auspices of the Indian Academy of Pediatrics (IAP) and Postgraduate Department of Pediatrics, Narayana Medical College & Hospital, Nellore, AP
On 29-30th March 2008

Invited accredited Experts to conduct the Workshop
Venue: NMC Lecture Gallery, NMC, Nellore 524002, AP
Registration fee: Rs. 2400 (IAP members), Rs 2000 (Postgraduate Students, providing a certificate from their HODs)
Chairman
Dr. Suraj Gupte, MD, FIAP
Professor & Head
Postgraduate Department of Pediatrics, Narayana Medical College,
Chintha Reddy Palem, Nellore 524002, AP
Phone 9490492804
E-mail: <recentadvances@yahoo.co.uk>

For Registration, please rush:
Dr. Chandra Mohan Kumar
Asst Professor of Pediatrics
Narayana Medical College,
Chintha Reddy Palem, Nellore 524002, AP
Phone 9490166172
E-mail: <cmkumar1@rediffmail.com>

Note: In view of limited seats, an early registration shall be appreciated.
VENTILATORS

* Jayashree M
** Rakshay Shetty

Abstract: Ventilators are microprocessor controlled devices used to augment or replace patient’s respiratory muscles in performing the work of breathing. A basic knowledge of controls, variables and alarms in a ventilator and features available in newer modifications will facilitate the practitioners to choose a ventilator to suit his requirement. Besides conventional ventilators and transport ventilators, newer modifications such as continuous positive airway pressure (CPAP) ventilators, high frequency ventilators (HFV) and non-invasive ventilators (NIV) are discussed with some examples available in Indian market. Recommendations for basic features which should be available in a ventilator and guidelines for sterilization are also given.

Key words: Ventilators, Classification, Non-invasive, High frequency, Transport.

A ventilator is a machine designed to alter and transmit applied energy in a predetermined manner to perform useful work of ventilation. It is used to augment or replace the patient’s muscle in performing the work of breathing. The use of mechanical devices to assist ventilation became a clinical reality in the late 19th century. Most of the early ventilators were negative pressure ventilators. Artificial positive pressure ventilation became operational from the early 20th century. Over the years, ventilators have evolved into complex microprocessor controlled devices with multiple functioning capabilities. This has been further compounded with plethora of ambiguous and confusing new terminologies coined by each manufacturer. Understanding of each ventilator is crucial in management of patients, as artificial ventilation techniques are the most important skills for an intensivist. Classification of ventilators proposed by Mushin and Co published in 1980 is virtually irrelevant in today’s scenario. Task of understanding ventilators has been simplified by the organized approach suggested by Chartburn (Table 1).

Power input

All ventilators require a source of power that can be used to perform the work of ventilating the respiratory system. Input power can be electric or pneumatic.

Electric: Electrically powered ventilators utilize 120V, 60Hz alternating current or 12 V DC for a power source. Common ventilator batteries are the lead- acid type, which supply approximately 2.5 amp hours of energy. This powers a ventilator for upto 1 hour and requires 8-12 hours of recharge.

Pneumatic: Ventilators operated by pressurised gas have internal pressure reducing regulators, so that the normal operating pressure is lower than the source pressure. The piped gas sources in hospitals are regulated to 50 psi (pounds per square inch).
Table 1: Classification Scheme for Mechanical Ventilators

<table>
<thead>
<tr>
<th>Power Input</th>
<th>Electric</th>
<th>Pneumatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Scheme</td>
<td>Control Variable</td>
<td>Phase Variable</td>
</tr>
<tr>
<td>Control variables</td>
<td>Conditional Variable</td>
<td>Output Waveform</td>
</tr>
<tr>
<td>Alarms</td>
<td>Input Power Alarms</td>
<td>Control Circuit Alarms</td>
</tr>
<tr>
<td>Alarms</td>
<td>Output Alarms</td>
<td></td>
</tr>
</tbody>
</table>

Control scheme

Control scheme basically deals with how a machine can be controlled to replace or augment the natural function of breathing. If a respiratory system is compared to a simple electric circuit, then compliance is analogous to capacitance, flow resistance is analogous to electric resistance and pressure is analogous to voltage source.

Thus, by applying equation of motion we have, pressure (muscle pressure + ventilatory pressure) = (elastance × volume) + (resistance × flow). i.e. Pressure (muscle pressure + ventilatory pressure) = elastic load + resistive load.

Muscle pressure is the transrespiratory pressure exerted by the ventilatory muscles during inspiration. Here, pressure, volume and flow are expected to change with time and are hence called as ‘variables’. Elastance and compliance are assumed to remain constant and are hence called as ‘parameters’.

Using mathematical terms, it becomes clear that the ventilator is able to control only one variable (the independent or control variable).

Any of the four variables (pressure, volumes, flow, and time) can be controlled making it the independent variable while others become dependent. Which variable becomes dependent is determined by selection of control variable. For example, in pressure controlled ventilation, pressure becomes the independent variable; hence the pressure waveform remains constant, whereas volume waveform depends on the shape of pressure waveform and also the resistance and compliance of the respiratory system.

This forms the basis for classifying ventilators into ‘pressure, volume and flow controllers’. If none of these are controllers, then it is likely to be time controlled. This happens only in the high frequency ventilators. It is important to remember that at any time only one variable can be controlled (Fig 1).

Each ventilator needs a controller system to achieve a desired output. These are of two types- ‘open loop control’ and ‘closed loop control’ or feedback control. Feedback control is also called as ‘servo control’. Open loop control does not use the output information to modify its input whereas servo control constantly takes feedback from its output to modify its new input. This helps in maintaining constant inspiratory pressure, volume or flow waveforms in the presence of changing loads. Some newer ventilators have a system of dual control. They are of two types; dual control between breaths, dual control within breath.

Control variables

The control variables are the variables set or controlled by the ventilators to deliver the predetermined energy to the respiratory system.

Pressure controllers: are ventilators that control either the airway pressure (increasing it above the ambient pressure for inspiration) or the pressure surrounding the body (decreasing it below airway opening pressure for inspiration).
Based on this ventilators are classified as positive or negative pressure type ventilators.

**Volume controller**: A ventilator maintains constant tidal volume regardless of the varying workload (compliance and/or resistance).

**Flow controller**: also has a constant volume waveform in presence of changing compliance or resistance. Here however volume is not measured or used as feedback signal to alter flow.

**Time controller**: the only variables controlled are inspiratory and expiratory times thereby both
pressure and volumes will be affected by changes in lung mechanics.

**Phase variables**

A ventilator-supported breath may be divided into four distinct phases: a) Change from expiration to inspiration, b) Inspiration, c) Change from inspiration to expiration, d) Expiration.

During each phase, one particular variable (pressure, volume, flow or time) is measured and used to start, sustain and end the phase. These are referred to as phase variables.

**Trigger:** Variable that helps in initiating inspiration is called as trigger variable.

Time trigger: A time triggered breath is initiated and delivered by the ventilator when a preset time interval has elapsed. The ventilator, will deliver a breath without regard to patients breathing effort or requirement.

Pressure trigger: This allows better ventilator-patient synchrony. Pressure triggering uses the drop in airway pressure at the beginning of inspiratory effort to signal the ventilators to begin inspiration. Pressure triggering requires more effort on the part of patient.

Flow trigger: A continuous flow passes through the ventilator circuit and returns to the ventilator (i.e. delivered flow = returned flow). As the patient initiates a breath, part of the delivered flow goes to the patient and hence the return flow to ventilator is decreased triggering to supply more flow. Flow triggering is more sensitive to patient’s inspiratory effort and hence imposes less inspiratory work compared to pressure trigger.

**Sensitivity:** The amount of negative pressure below the end expiratory pressure required to trigger ventilators is called the sensitivity e.g. 3 cm H$_2$O. If a ventilator is more sensitive to patient’s efforts, it is easier for patients to trigger.

The ability of the ventilator to sense patient effort and respond quickly with sufficient flow to meet patient’s demands is very important to achieve ventilator – patient synchrony.

**Limit:** A variable which reaches a preset value during inspiration is called a limit variable. During a ventilator supported breath, volumes, pressure and flow all rise above their respective baseline values. The inspiratory phase is defined as time interval from start of inspiratory flow to the start of expiratory flow. The inspiratory flow time is the interval from start of inspiratory flow to the end of inspiratory flow. This is followed by inspiratory pause time which starts from the end of inspiratory flow to the start of expiratory flow. Volume, pressure or flow could be the limit variable depending upon the mode selected.

**Cycle variable:** A variable that is measured to terminate inspiration is called cycle variable. Inspiration ends or is ‘cycled off’ when some variable has reached a preset value. This variable that is measured to terminate inspiration and begin expiration is called the ‘cycle variable’. Clinicians generally tend to use the terms cycle and limit interchangeably. One must understand that the limit variable attains peak value before end inspiration, while inspiration is terminated when the cycle variables preset value is reached. For example in pressure limit, if limit is set to 20 mmHg, then once pressure rises to 20 mmHg during inspiration, it stays at 20 mmHg till the end of inspiration which is decided by the cycling variable. Time is the most common cycle variable that is set. Time is usually the cycle variable in mandatory breaths, where as flow is the cycle variable in spontaneous breaths.

**Baseline variable:** A variable that is controlled during expiration is called baseline variable. Expiratory time is defined as the time interval form the start of expiratory flow to the end of expiratory flow. In vast majority of clinical
situations, end expiratory pressure and thus end expiratory volume are controlled during expiratory phase.

**Conditional variables**

Ventilator usually creates a specific pattern of control and phase variables for a breath. This pattern either might remain constant or might change with breath (example- mandatory Vs spontaneous). Simple example is Synchronized Intermittent Mandatory Ventilation (SIMV) mode where characteristics of mandatory breath and spontaneous breath could be different. If the ventilator fails to detect the patient’s inspiratory effort during a pre-determined time, then a mandatory breath is delivered. If it detects inspiratory effort during the SIMV window, assisted breath is delivered. If the patient’s effort occurs after the SIMV window, then a spontaneous breath is allowed. Four different breath types can be described depending upon whether the ventilator or patient controls the triggering, limiting and cycling variables (Table 2).

**Output waveforms**

These are graphical representations of the control or phase variables in relation to time. Conventionally they are presented in the order of pressure, volume and flow. Inspiration is depicted by positive (above horizontal axis) and expiration by negative (below horizontal axis). The horizontal axis represents the time in seconds. The vertical axis represents the measured variable (e.g. pressure/flow).

Waveforms assist clinicians in detecting auto PEEP (Positive end-expiratory pressure), ventilator- patient dyssynchrony, resistance, compliance and other characteristics which when detected help in smooth ventilation.

**Alarms**

Alarms are designed to alert the clinician to undesirable technical or patient events. The type of alarms may be broadly categorized into 3 groups:

**Input alarms:** These alarms notify clinicians on the loss of input power (electrical or pneumatic).

**Control circuit alarms:** These alert clinician to setting or parameters that are not within acceptable ranges. They warn the operator that ventilator self test has failed or that the selected control – variables are incompatible.

**Output alarms:** An output alarm is activated when the value of a control variable (pressure, volume, flow or time) exceeds or falls below preset values e.g. high or low peak inspiratory pressure and end expiratory pressure, high or low tidal volume and frequency.

**Table 2: Classification of the Available Mechanical Ventilator Breaths**

<table>
<thead>
<tr>
<th>Breath Type</th>
<th>Trigger</th>
<th>Limit</th>
<th>Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandatory</td>
<td>machine</td>
<td>machine</td>
<td>machine</td>
</tr>
<tr>
<td>Assisted</td>
<td>patient</td>
<td>machine</td>
<td>machine</td>
</tr>
<tr>
<td>Supported</td>
<td>patient</td>
<td>machine</td>
<td>patient</td>
</tr>
<tr>
<td>Spontaneous</td>
<td>patient</td>
<td>patient</td>
<td>patient</td>
</tr>
</tbody>
</table>
Newer modifications on conventional ventilation techniques

Pressure regulated volume control (PRVC): In this type of control, one set point is automatically adjusted to achieve another set point as the patient’s condition changes. Mandatory breaths are pressure limited and the limit is automatically adjusted between breaths to achieve the preset tidal volume\(^5\). (e.g. Maquet Servo i and Drager Evita 4).

Adaptive support ventilation (ASV): In this type of control, one set point is automatically adjusted to optimize another set point according to some models whose output can be maximized or minimized dynamically. Each breath is pressure limited and the limit is adjusted between breaths using ventilatory mechanics to reduce the work of breathing. Patient is breathing spontaneously\(^5\). (e.g. Hamilton Gallileo).

Airway pressure release ventilation (APRV): This mode provides mechanical ventilation without raising the airway pressures above CPAP level and hence the barotraumas and adverse hemodynamic effects seen with other conventional modes are minimized\(^6\) (e.g. Drager Evita 4).

Table 3: Different brands of ventilators

<table>
<thead>
<tr>
<th>Principal Manufacturer</th>
<th>Indian agent</th>
<th>Approx. Cost</th>
<th>Modes available</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gallileo</strong></td>
<td>M/SHamilton MedicalAG, Switzerland</td>
<td>M/S Trivitron, Chennai</td>
<td>Rs 12 lacs each</td>
</tr>
<tr>
<td><strong>Newport Breeze E- 500 E- 360</strong></td>
<td>Newport, U.S.A</td>
<td>M/S Pulmocare New - Delhi</td>
<td>Rs 6-7 lacs each</td>
</tr>
<tr>
<td><strong>Evita 4 Dura</strong></td>
<td>M/S Drager Medical Germany</td>
<td>M/S HL Medical System, New Delhi</td>
<td>Rs 10 lacs each</td>
</tr>
<tr>
<td><strong>Servo i</strong></td>
<td>M/S Maquet, Sweden</td>
<td>M/S Maquet Delhi, India</td>
<td>12 lacs each</td>
</tr>
<tr>
<td><strong>‘T’ Bird Vela</strong></td>
<td>Viasys Health care USA</td>
<td>M/S Rohanika,</td>
<td>7-8 lac each</td>
</tr>
<tr>
<td><strong>Savina</strong></td>
<td>M/S Drager Medical Germany</td>
<td>M/S HL Medical System, New Delhi</td>
<td>7-8 lac each</td>
</tr>
<tr>
<td><strong>Amadeus</strong></td>
<td>M/SHamilton MedicalAG, Switzerland</td>
<td>M/S Trivitron, Chennai</td>
<td>7-8 lac each</td>
</tr>
</tbody>
</table>

\(\text{PRVC : Pressure regulated volume control; APRV : Airway pressure release ventilation; ASV: Adaptive support ventilation; PAP : Positive airway pressure; VTPC : Volume targetted pressure controlled.}\)
The different models of conventional ventilators along with their approximate cost and marketing agencies are given in Table 3.

**Continuous positive airway pressure (CPAP)**

CPAP refers to maintenance of positive airway pressure throughout the respiratory cycle with no positive pressure breaths being delivered to the patient. The patient breathes spontaneously. CPAP helps in recruiting the closed alveoli thereby increasing the functional residual capacity (FRC) and decreasing the work of breathing. It is useful in lung conditions that are characterized by increase in closing volume and hence the goal would be to keep the level of CPAP above the critical opening pressure.

**Indications for CPAP:** a) Acute lung injury, b) Weaning from mechanical ventilation, c) Post extubation, d) Tracheomalacia.

CPAP can be delivered in many ways. It can be delivered without a ventilator with an assembly that requires continuous gas flow, an underwater column, humidification device, a valve to maintain positive pressure above atmospheric pressure, pressure manometer, ports for monitoring oxygen and CO₂ and connectors for face mask or endotracheal tube. Nowadays several CPAP kits are available in the market. (e.g Bubble CPAP, Vygon CPAP kit etc)

**Endotracheal CPAP:** This is the most reliable method of applying CPAP.

Advantages are: a) Precise control over airway pressure and FiO₂, b) Provides conduit for tracheobronchial toileting, c) Maintenance of enteral feeding through nasogastric tube, d) Mechanical ventilation if needed can be initiated easily.

Disadvantages: Are the same that are associated with an artificial airway.

**Nasal CPAP:** This can be provided by nasal prongs, nasal cannula, shortened endotracheal tube placed in the nasopharynx or by nasal masks. This is more useful in infants who are obligate nose breathers.

Advantages: It is easy and requires less skill for application. Being non invasive in nature, it does not carry the disadvantages of an endotracheal tube.

Disadvantages: Nasal prongs are prone for obstruction, require frequent suctioning and good humidification devices. They might even increase the work of breathing.

**Face mask CPAP:** CPAP is provided by application of tight fitting face mask. It is easy to apply but the patient has to be alert and cooperative. The tight fitting mask can cause pressure lesions over the face. Gastric distension with vomiting and aspiration can be another undesirable problem with mask CPAP.

**Side effects of CPAP:** a) Barotrauma, b) Decrease in cardiac output, c) Aggravation of intracranial hypertension, d) SIADH.

**Contraindication for CPAP:** Apnoea due to neuromuscular weakness, progressive hypoventilation, fatigue of respiratory muscle, facial trauma.

**Brands Available:** Bubble CPAP kits (Indigenous), Vygon CPAP kits (Approx Cost : Rs.40,000/-)

**High frequency ventilation (HFV)**

HFV refers to diverse modes of ventilation characterized by supraphysiological ventilatory frequencies (>60 cycles/min) and low tidal volumes (less than or equal to physiological dead space seen during conventional mechanical ventilation).
Four methods of high frequency ventilation have been described: a) High frequency positive pressure ventilation (HFPPV), b) High frequency jet ventilation (HFJV), c) High frequency oscillatory ventilation (HFOV), d) High frequency chest wall oscillation (HFCWO).

HFPPV, HFJV, HFOV are the usually used modes.

Proposed advantages of HFV: 1) Reduces peak, mean airway pressures and improves cardiovascular stability, 2) Decreases risk of barotraumas, 3) Reduces sedation requirement, 4) Decreases the incidence of hypoxia during tracheobronchial toilet, 5) Allows adequate ventilation with a disrupted airway (eg. bronchopleural fistula), 6) Permits mechanical ventilation during bronchoscopy, 7) Improves operating conditions eg in thoracic surgery, 8) Allows ventilation through narrow catheters and thus increases access during laryngeal and tracheal surgery.

Disadvantages: a) It requires specialized equipment, b) It has inherent dangers of high pressure gas flows, c) Humidification of inspired gases is difficult, d) Tidal volumes markedly affected by changes in respiratory compliance, e) Monitoring of ventilation parameters is difficult, f) Difficult to predict minute ventilation from ventilator.


Indications for initiation (switch from conventional to high frequency): 1) FiO₂ requirement is >60%, 2) Mean airway pressure >20 cm H₂O, 3) PEEP > 15 cm H₂O, 4) Plateau pressure >30 cm H₂O.

Available Brands

Drager Babylog 8000: This ventilator is specifically designed for infants up to 10 kilograms (22 pounds). It is capable of both volume and pressure ventilation. This provides the following modes: Assist control (AC), SIMV, PSV (pressure support ventilation), Volume guarantee (VG), and independent Expiratory Flow (VIVE). This provides HFO for only neonates up to 2 kg. The advantage is that single machine can provide conventional and HFO. Cost: Approx 12-13 lakhs

Sensormedics 3100A: It offers only high frequency oscillatory ventilation. It has an active inhalation/exhalation, driven by a moving piston and diaphragm. It requires special stiff non-compliant ventilator circuit. Can be utilized for a wide range of weights including patients who weigh more than 35 KG. This oscillator has been approved for use in children by FDA since 1995. Cost: Approx 15-16 lakhs.

SLE 5000 infant ventilator: Offers conventional as well as HFOV in the same machine. It can be used to ventilate patients from 300gms-20Kg weight. The same patient circuit can be used for conventional and HFO ventilation minimizing the risk for lung decruitment. Cost: Approx 15-16 lakhs

Noninvasive ventilation

It is defined as provision of assisted ventilation without the use of an artificial airway (endotracheal tube or tracheostomy). Although negative pressure ventilators are available to provide non invasive ventilation, non invasive positive pressure ventilators (NPPV) are more commonly used. NPPV can be provided by a conventional mechanical ventilator or with specially designed ventilators (eg, BiPAP.
BiPAP is the usual modality used to provide NPPV. Face mask CPAP can also be considered as a form of NPPV.

**BiPAP (Bi level positive airway pressure)**

It is an airway pressure strategy that provides independent positive airway pressures to both inspiration and expiration, called IPAP (inspiratory positive airway pressure) and EPAP (expiratory positive airway pressure). IPAP provides positive pressure breaths and improves hypoxemia and hypercapnia. EPAP is in essence CPAP and it improves oxygenation by increasing functional residual capacity.

**BiPAP has following modes**

Spontaneous: In this mode no mandatory breaths are provided.

Spontaneous/time: It is usually a back up mode. It responds to patient’s breaths and gives IPAP and EPAP, but if patient fails to initiate breath, it provides a positive pressure breath at a preset frequency.

Timed mode: Here the unit provides both IPAP and EPAP at preset frequency and the patient is allowed to breathe spontaneously.

CPAP mode: Here IPAP is equal to EPAP thus providing only a single level of airway pressure throughout the respiratory cycle.

Nasal mask, full face mask or nasal pillows are the various interfaces that are available to provide BiPAP.

**Advantages:** 1) Avoidance of endotracheal intubation, 2) Decreased duration of ventilation, 3) Decreased incidence of pneumonia, 4) Decreased incidence of sinusitis, 5) Improved ability to communicate, ability to drink and eat, 6) Preservation of effective cough (only in nasal NPPV), 7) Decreased need for sedation and paralysis.

**Potential risks:** 1) Facial skin necrosis, 2) Increased aspiration risk, 3) Increased duration of ventilation in patients who fail NPPV, 4) Difficulty in providing adequate calories enterally, 5) Decreased ability to cough (full face mask), 6) Increased myocardial ischemia.


**Contraindications: Absolute -** 1) Hemodynamic instability, 2) Patients at risk for aspiration, 3) Inability to clear secretions.

**Relative:** 1) Inability to properly fit the mask, 2) Uncooperative patient, 3) Morbid obesity.

**Available Brands:**

BiPAP machine marketed by Respironics, Inc., Murrysville, PA. (Cost: Approx 1 lakh)

The Evita 4 series marketed by Drager also provides NIV. (Cost: Approx 10 lakhs)

**Transport Ventilators**

**Prehospital Transport**

Transport ventilators for prehospital care and following CPR are machine triggered, volume limited and time cycled devices. 

The American Heart Association (AHA) has laid down criteria for transport ventilators:

1. Operate in all environmental conditions and extremes of temperature.
2. Minimal gas consumption (0 to < 5L/Min).
3. **FiO\(_2\)** of 1.0

4. Peak pressure limit of 60 cm\(\text{H}_2\text{O}\) with an option of 80 cm\(\text{H}_2\text{O}\)

5. Audible alarm when the peak pressure limit is exceeded.


7. Inspiratory time of 2.0 seconds for adults and 1.0 sec for children with peak inspiratory flow rates of 30 L/min and 15L/min respectively.

8. At least 2 respiratory frequency settings.

9. Lightweight (2-5kg), compact.

10. Lightweight connectors with standard 15/22 mm connector.

The operation of the ventilator should be simple with minimum number of controls. Pneumatic (pressurized power source) is useful as it does not require current supply. These ventilators do not require variable FiO\(_2\), CPAP or any other mode. As most patients are apnoeic and have required CPR, controlled mandatory ventilation is needed.

Breathing circuit and assembly should be simple and less time consuming. Battery powered ventilators should be equipped with a “low battery” signal that indicates when 1 hour of power remains. Adequate visual and audible alarms should be incorporated in the system for battery, loss of O\(_2\) supply and high inflation pressures.

Incorporation of a breathing value (inhalation/exhalation) is a distinct feature in prehospital transport ventilators. This valve is connected to the ventilator by corrugated or high-pressure tubings and directs inspiratory and expiratory gases to and from the patient.

**Intrahospital transport**: Ventilators used for intrahospital transport should have intermittent mandatory and assisted ventilatory modes. Separate controls should be available for respiratory frequency and tidal volume (\(V_T\)). The application of PEEP/CPAP should be possible. Adjustable FiO\(_2\) is desirable especially in neonates and children given the risks of oxygen toxicity. Alarm systems, size and weight, power input and gas consumption specifications are all similar to the pretransport ventilators.

A delicate balance between operational flexibility and simplicity must be maintained. Humidification is generally provided with passive systems heat-moisture exchange (HME.), which collect patient’s own respired heat and moisture and return them during the following inspiration.

**Available Brands**: Crossvent 3 (infant) transport ventilator and Crossvent V (infant/neonate/pediatric)-Marketed by Trivitron Ltd.

**How to choose conventional ventilators (ECRI recommendations for purchase)**

There are several Indian agencies offering highly sophisticated and expensive ventilators. Prior to purchasing any ventilator, it is important to evaluate its capabilities. The minimum performance requirements for intensive care ventilators are separated into two categories-basic and mid/high complexities.

**Basic features**: Suitable for all sizes-from neonate to adult. Options for CMV, SIMV, SIMV+PSV, PSV, CPAP modes. Deliver accurate predetermined stable FiO2 from 21-100%. Delivered O\(_2\) should be monitored with an oxygen analyzer. Controls should be available for pressure level, tidal volume, breath rate, inspiratory time or I: E ratio, FiO2, PEEP/CPAP, pressure support and trigger sensitivity. Display data for all set parameters should be available (pressures, tidal volume and oxygen.
concentration etc). Should have a comprehensive audible and visible alarm system. Alarms are a must for inspiratory pressures (high and low), low CPAP/PEEP, minute volume (high and low), gas supply loss and power failure.

Minimal circuit resistance and impedance should be a feature to allow spontaneous breathing without increased work of breathing. Oxygen consumption should be limited with electrical and gas safety. Sterilization for circuits and reusable accessories should be simple. Adequate battery back up for at least one hour should be available. Assembly and operation should be simple and user friendly. Upgradation if necessary must be possible at a later date. Resources available and cost of the ventilator are also important. The agency should provide high level back up and maintenance service.

**Additional features:** Additional advanced modes are PRVC, ASV, APRV. Measurement of auto PEEP, leak, compliance and resistance are additional features, if available, will definitely help. Graphics have become an important component of ventilation today. Hence display of graphics should be available. Facilities for inline suction and nebulisation are other options.

**Guidelines for sterilization or disinfection of equipments and devices**

- Clean all equipments and devices to be sterilized or disinfected.

- For equipments and devices that come in direct contact with mucous membranes of the lower respiratory tract that are not sensitive to heat and moisture use steam sterilization (by autoclaving) or high-level disinfection by wet heat pasteurization at > 70°C (>158°F) for 30 minutes. For equipment or devices that are sensitive to heat and moisture, low-temperature sterilization methods should be used. After disinfection, appropriate rinsing, drying, and packaging, should be done taking care not to contaminate the disinfected items.

  - Preferentially use sterile water for rinsing reusable semicritical respiratory equipment and devices when rinsing is needed after they have been chemically treated. If this is not possible, rinse the device with filtered water or tap water, and then rinse with isopropyl alcohol and dry with forced air or in a drying cabinet.

  - Internal machinery of mechanical ventilators does not need routine sterilization or disinfection.

  - Routine change of the breathing circuit (i.e., ventilator tubing and exhalation valve and the attached humidifier on the basis of duration of use,) is no longer recommended unless it is visibly soiled or mechanically malfunctioning.

  - Condensate that collects in the tubing of a mechanical ventilator should be periodically drained and discarded taking precautions not to allow the condensate to drain towards the patient. Gloves should be worn while performing this procedure or handling the fluid.

  - Use sterile water to fill bubbling humidifiers.

  - A heat-moisture exchanger (HME) should be changed when it malfunctions mechanically or becomes visibly soiled. An HME that is in use on a patient should not be routinely changed more often than every 48 hours.

  - Between treatments on the same patient, small-volume medication nebulizers (in-line) should be cleaned, disinfected, rinsed with sterile water (if rinsing is needed), and dried. Only sterile fluid should be used for nebulization. Whenever possible, aerosolized medications in single-dose vials should be used. If multidose medication vials are being used, manufacturers’ instructions for handling, storing, and dispensing the medications should be complied with.
• Between uses on different patients, mist tents and their nebulizers, reservoirs, and tubings must be replaced with those that have been subjected to sterilization or high-level disinfection.

• Mist-tent nebulizers, reservoirs and tubings that are used on the same patient should be subjected to daily low-level disinfection (e.g. with 2% acetic acid) or pasteurization followed by air-drying.

• Between uses on different patients, reusable hand-powered resuscitation bags should be sterilized or subjected to high-level disinfection.

• Between uses on different patients, clean reusable components of the breathing system or patient circuits, T-piece, reservoir bag, humidifier, and tubing should be cleaned and then sterilized or subjected to high-level liquid chemical disinfection or pasteurization in accordance with the device manufacturers’ instructions.

Points to Remember

• Understanding the controls, variables and alarms, will facilitate proper choice of a ventilator suited to one’s level of practice and optimise patient management.

• Newer modifications such as pressure regulated volume control, adaptive support ventilation and airway pressure release ventilation are designed to minimise barotrauma.

• Non-invasive positive pressure ventilation in the form of Bi PAP and face mask CPAP are increasing by used as they are less injurious.

References


Abstract: Modern day newborn care is equipment intensive. Phototherapy, radiant warmer and incubator are equipments without which a level II NICU can not be imagined. Effective use of special blue light phototherapy has almost eliminated the need for exchange transfusions for hyperbilirubinemia. Radiant warmers are easier to use and as effective as the costlier incubators. Incubators with good humidity control may be necessary to manage ELBW babies. Sound knowledge of how to use and maintain these equipments is necessary.

Key words: Phototherapy, Radiant warmer, Incubator, Equipment.

PHOTOTHERAPY (PT) UNIT

Effective use of good PT device has drastically reduced the need for exchange transfusions for hyperbilirubinemia.

Indication for PT - Management and prevention of hyperbilirubinemia

1. Near term and term babies: Guidelines for initiating PT are as per AAP recommendations.

2. Preterm / low birth weight babies: Currently, there are no evidence based guidelines. All

guidelines are empirically designed, keeping in mind the greater vulnerability of low birth weight babies.

3. Prophylactic PT: This has been described in ELBW with bruises and in Rh isoimmunized babies. But, it is easy to understand that PT will not act if there is no bilirubin.

Mode of operation

Principle of PT: Bilirubin under the baby’s skin absorbs light of a specific wavelength (400 – 500 nm, blue light). It is converted to a water soluble isomer (Z-isomer converted to E-isomer, a reversible reaction) and excreted. The clinically important reaction is conversion of bilirubin to lumirubin.

Types of PT

There are different PT machines based on the type of light emitted (blue, green, white, halogen etc) and the type of source [standard tube lights, compact fluorescent lamps (CFL), light emitting diode(LED), fiber optic – bili-blanket].

PT units commonly available in Indian market are blue light or white light fluorescent tubes.

Factors affecting effectiveness

1. Phototherapy light source: a) Special blue lights (blue – green spectrum) are most effective. Light of this wavelength is best not only in penetrating the skin but also in its absorption by bilirubin and is commercially available as F20T12/BB (General Electric, Westinghouse, Sylvania) or TL52/20W (Phillips, Eindhoven,
The Netherlands) and is better than regular blue light (regular blue tubes F20T12/B), b) **Spectral irradiance (intensity in specific spectrum)**: Photo-isomerization is dose dependant. Increase in intensity of PT (by using more lights or bringing the lights closer to the baby) results in a faster and greater drop in serum bilirubin. Best effect is noted at more than 30 micro watt / cm² per nm. Special blue lights at 10-15 cm produce about 35 micro watt / cm² per nm. Halogen lamps should not be brought closer to baby than recommended (risk of burns). **Intense PT** is defined as special blue light used in appropriate dose i.e. more than 30 microwatts / cm² per nm, kept as close to the baby as possible without producing hyperthermia. 30 to 40 % decrease in serum bilirubin can be expected in 24 hours with special blue lights and 6-20 % with regular blue.

2. **Clinical factors**: a) Area of skin exposed to PT – Double surface PT (over head and through a transparent baby cot from below) is more effective. Lining the warmer or incubator walls with aluminum foil / white cloth for internal reflection, increases effectiveness of PT³, b) If initial bilirubin levels are higher, drop in bilirubin levels is faster, c) PT is less effective in hemolytic jaundice, active hemolysis and alternate therapies like IVIG and exchange transfusion must be planned in addition to PT, d) Intermittent PT is as effective as continuous PT. PT can be interrupted for breast feeding or parent visit. But, if bilirubin values are nearing exchange zone, it is best to deliver continuous PT till baby is safe. e) Baby comfort is extremely important to allow continuous / longer hours of PT eg. If double surface PT is used, a good bubble sheet or water bed must be used. Hyper / hypothermia should be monitored and corrected. f) Good feeding and stool output decreases entero-hepatic recirculation of bilirubin. Monitor urine output, daily weight and hydration status (serum sodium, urine specific gravity) to obtain best results. g) Once a baby is treated by PT, the skin color is no more a reliable measure of serum bilirubin and serum bilirubin must be assayed frequently (6-12 hourly).

3. **Advantages**: PT is a simple to use, non-invasive and inexpensive treatment for hyperbilirubinemia.

4. **Disadvantages**: Serious side effects are rare.

a. **Dehydration**: Large and unpredictable amount of insensible water losses can occur by evaporation through skin. An anticipated approximate 20-40 ml / kg / day may be added to fluid planned for the day.

b. **Hyper / hypothermia**: In addition to the necessary wave length of light, the unit also emits heat, hence babies may develop hyperthermia. As the babies are kept completely naked under PT, preterm and low birth weight babies are at risk of hypothermia.

c. **Skin rashes**: Macular, erythematous rashes can develop on exposed skin. They are transient and require no specific therapy.

d. **Risk of bright light to eyes**: The eyes must be covered with eye patches / bands. The plexiglass of the PT unit also absorbs a major proportion of ultraviolet rays that can pass through cornea.

e. **Risk to reproductive tissues**: There is a presumed risk of mutations in reproductive cells. In boys, the scrotum (testes) are protected by using a small diaper. Large diapers cover a large area of exposed skin and are likely to reduce efficacy of PT, and must be avoided. In girls the ovaries are deep intra-abdominal and need no specific protection.

f. **Separation from mother**: PT reduces opportunities of mother baby contact and bonding that forms a vital stimulus for breast feeding. Fiber optic bili-blanket allows mother to hold the baby when PT is delivered⁴.
g. **Conjugated hyperbilirubinemia:** PT can result in bronzing / blistering. Parents must be informed about the risk of the reversible discoloration. But, presence of direct bilirubin alone is not a contra-indication for PT and decisions to treat should be made on total bilirubin levels and not on “unconjugated levels”.

h. Blue lights can cause nausea and headache to personnel working in the unit. Hence, most units use a combination of blue and white day light tubes.

**How to buy a PT unit**

1. Special blue light is preferred over white light.

2. Compact fluorescent lamps (CFL’s) are less bulky than standard length tube lights. They are easy to place around the baby and easy to store. Currently, there is not enough evidence to prove them as more effective. These lamps are costlier and a ready supply of spare tubes must be ensured before purchase.

3. Caution: Ordinary white tube lights covered with a blue film / color are not effective and not ideal for use.

**Cost**

Rupees 20,000 (special blue) to Rupees 60,000 CFL

**Regular maintenance**

The luminosity (intensity of light) decreases with use. It is important to check efficacy at regular intervals using a flux meter (photo radiometer). (The manufacturer can be requested to check at predetermined periods). If this is not possible, the tubes must be changed after “hours of use” specified by manufacturer (approximately 3000 hours for special blue lights and 2000 hours for white light). The PT units must have a chronometer that clocks its use. Over heating of units (due to poor ventilation) can result in accelerated loss of efficacy.

**Note:** The photo radiometer measurements depend on the spectrum it measures and also the place where it is placed in the baby cot. Hence, it is preferable to have average measurements from different relevant points on the baby cot and serially use the same machine to detect drop in efficacy.

**Cleaning / sterilization**

The units are likely to gather dust and must be wiped with a light detergent before use. An aldehyde based disinfectant must be used to clean the PT unit in between babies.

**New developments**

1. **Bili-blanket:** The source of light is far from the baby. It is transmitted through fine fiber – optic cables arranged as a blanket. This can be wrapped around the baby, and allows mother to hold the baby during PT. It is as effective as special blue lights.

2. **LED (Gallium Nitride) lights** produce light at a very steady intensity in the specified spectrum required. They are as effective as special blue. LED lights have a longer life and consume less power

**OVERHEAD RADIANT WARMER (OPEN CARE SYSTEM)**

The newborn baby is most comfortable in the thermo-neutral zone – an environmental temperature at which the baby maintains body temperature in normal range (36.5-37.5 C), also has minimum basal metabolism and least oxygen consumption and grows best. Vulnerability of the newborn babies to hypothermia / cold stress and its serious consequences makes it necessary to provide an external source of heat.
**Indications**

1. Resuscitation of newly born babies
2. Management of sick babies in Emergency Rooms
3. Managing sick babies in nurseries / ICUs
4. Neonates undergoing surgery

Radiant warmers are considered better than incubators in care of sick term and preterm babies. They allow direct observation and easy access to baby. Use of RW requires no special nursing training. They are easy to clean, hence, less likely source of infections. Some prefer incubators for ELBW babies (birth weight less than 1000 gms), as the insensible water losses from immature skin is minimized.

**Mode of operation**

The RW has an overhead electric heating element that emits infra red rays and a parabolic reflector that focuses the heat onto the central part of the bassinet (baby cot). There are 2 modes – manual mode and servo mode.

1. **Manual mode**: The RW delivers heat at a graduated level; 25 %, 50 %, 75 % or 100 % heat (some machines can deliver at gradations of 10). Manual mode is useful for pre-warming of bed before receiving a baby or rapid warming of a recently transferred hypothermic neonate. It may also be used in situations where the probe cannot be reliably attached to the baby (eg – during a surgery).

Risks: The heat delivered by the machine is unaffected by needs of the baby, and there are risks of serious hyper / hypothermia. A baby should not be nursed in manual mode, unmonitored, for greater than 30 minutes. The temperature must be manually measured and the heater level readjusted.

2. **Servo mode**: Advances in microprocessor technology has allowed continuous monitoring of baby temperature and regulating heat output. The temperature is continuously measured by a thermometer (thermistor probe) attached to the baby. The temperature is then compared with the set (desired) temperature. The heater level (output) is now regulated by the microprocessor automatically to keep the baby temperature within a narrow range. Easily, this mode is far superior to manual mode.

**Thermistor probe**

This “electronic thermometer” is the most important element in servo controlled RW. The thermistor has 2 surfaces - the insulated surface and the metallic measuring surface. The measuring surface must be placed on a flat surface of skin far from moving parts (eg chest wall). The preferred site is on right hypochondrium, anatomically over the liver when the baby lies supine and on the flanks when the baby is nursed prone. If it is placed close to lower ribs, then breathing movements may disturb the contact with skin. This can result in serious errors in measurement of baby temperature.

The thermistor probe should be fixed by a skin friendly material (tegaderm). Skin loss is a portal for bacterial entry.

**Risks**: A completely dislodged probe can result in falsely low measurement and unduly high heat output resulting in serious burns. Hence, good RWs must have a probe off alarm for safety. Even in servo mode, manually measure axillary temperature every 6-8 hours (each nursing shift) and verify that the measurement is correct.

**Heater output display**

A sicker baby requires more heat to remain warm than a stable neonate. The heater output of the servo RW is displayed as small LED lights. All lights glowing indicating 100 % heater function, 50% indicate half the heat requirement by the baby, and no light display indicates no
heat requirement and hence a stable baby. In the author’s unit, the heater output is recorded as a vital sign. A recent heater output increase or a constant requirement of more than 50% has been found a sensitive indicator of serious illness like sepsis, shock, etc.

**Alarms**

The RW gives an alarm of “high” when baby temperature is more than 37.5 and low when less than 35.5°C (set temperature 36.5°C). Often alarms are overlooked, silenced, and the nursing staff / doctors are not trained to react appropriately.

**How to react to low / high alarm:**

- a. Manually check axillary temperature and verify that the thermistor is giving the right message.
- b. Check thermistor contact: Often a bad thermistor contact can show falsely low temperature. When the thermistor is on the abdominal surface and baby is prone, a falsely high temperature display occurs.
- c. Check environmental temperature: Use of PT units, over wrapping the baby and nursing baby close to windows on a hot day can result in hyperthermia. The reaction to the “high” alarm should be removal of the source of hyperthermia eg – switch off PT for a while, and not to mute or switch of the “noisy RW”!! Sometimes a wetprobe – ultrasound gel, baby’s urine, cleaning the baby by nurse can result in low reading by the machine.

**Clothing**

Covering the baby with clothes reduces insensible water losses. But, heavy / thick blankets must not be used to cover the baby. This does not allow radiant heat to reach the baby.

**Clean wrap**

This is a transparent thin plastic film. This can be used to cover the baby by stretching across the walls of the baby cot. This creates a microenvironment for the baby, reduces effect of environmental draught, unnecessary handling is discouraged and also reduces insensible water loss (like an incubator).

It is commercially used for covering food/vegetables under the microwave heater. (available in general stores). It is inexpensive (One meter costs less than 50 rupees).

**Locks / brakes**

It should be possible to immobilize the baby cot by brakes, to prevent accidental movements of baby cot (can lead to serious accidents like extubation of a ventilated baby, dislodgement of IV lines).

**How to buy a RW**

1. **Thermistor quality:** This is the most important part of the machine. It should be durable, flexible and spares should be readily available and inexpensive.

2. **Bassinet size:** The heating element must heat uniformly all parts of the baby cot. A large bassinet can allow the baby to lie in a corner where heating is not appropriate.

3. **“Memory”:** In case of power failure or fluctuation, the machine must return to the same mode (servo) that it was already working. We have noted serious accidents when the machine goes to factory set manual mode after a power failure.

4. **Swivel:** it should be possible to swivel the RW heating arm in order to accommodate a portable X-ray machine without disturbing the baby.

5. **“Additional features”** like a PT unit, a stop watch, a T-piece resuscitator, oxygen and suction devices definitely make the machine costlier. Also, in resource limited units in India, an independent PT is better than a fixed one as it may be used for another baby in need. Also, a
stand alone PT can also be brought closer to make it more effective.

6. **Extension board:** An extension board provided on the back of the warmer is found handy. It makes up for limited electrical points near the baby bed and also limits the electrical wires (syringe pump, monitor, PT etc) running across the unit. It is considered by some as an electric hazard risk.

7. **Detachable baby cot:** It is easy to move the baby without disturbing for short distances. The inherent risk is accidental moving of the baby cot from the focus of the heating element.

8. **Tiltable baby cot:** For nursing, eg. in suspected GERD, ventilation, etc.

9. There should be a slot below the baby cot for X-ray cassette, so that baby need not be touched/disturbed.

**Cost**

Ranges from Rupees 30,000 for an Indian make to over few lakhs for the branded foreign machines. It is best to invest in a brand that can provide service and spares readily. RW’s are more economical when compared to incubators. It is improper for a level II neonatal unit to invest in an incubator merely for facelift of the unit.

**Regular maintenance**

The thermistor measurements must be calibrated against a standard at regular intervals (at least once in 6 months).

**Spare accessories**

Spare thermistor probes and examination light should be available. Company must check and replace heater element.

**Cleaning**

The baby cot and warmer must be wiped daily with a mild soap solution (with the baby inside) to remove organic secretions like blood, urine, oral secretions etc and spilled IV fluids, as these are source of infections. Between babies / once a week, the machine must be cleaned with an aldehyde based disinfectant (even sprays are available). The transparent plastic surfaces must not be wiped with alcohol based solution – this will scratch the surface and make it opaque.

**New developments**

Now machines are available that combine the benefits of RW and incubator. On the press of a button, the incubators walls rise upwards, allow a nursing procedure and then return on request as an incubator. During the procedure it functions like a servo RW. Currently, it is very expensive.

**INCUBATOR**

The incubator, a machine for thermoregulation, was once synonymous with newborn care. The complexity of design makes it necessary to train well to operate and clean. Also, scientific trials have failed to demonstrate the perceived benefits in thermoregulation. Hence, the RW is preferred especially in resource limited level II nurseries / NICU. Only units that regularly care for ELBW babies must buy incubators.

**Indications**

Small, extremely preterm babies are thermo labile, and also likely to lose unpredictable and large amount of water (through skin). Such babies are likely to benefit by an incubator.

**Mode of operation**

**Principle of heat transfer to baby**

**Forced convection:** A fan produces currents of air that get heated over a heater coil (placed in a unit below the baby cot). The warm air circulates
in the canopy around the baby. The incubator protects the baby from draughts of outside air, produces a microenvironment, and thus reduces convective heat losses.

**Humidity:** The “humidity” inside can be raised much higher than that of the environmental level. The humidity can be raised till fogging of the walls start occurring without loss of visibility. This reduces evaporative heat loss and insensible water losses and makes fluid management easier (ELBW babies on first day may lose up to 60-100 ml / kg / day in a RW!!).

The canopy inside a double walled incubator traps an insulating column of air that reduces radiant heat losses.

**Modes**

**Skin mode:** same as servo mode of RW

**Air mode:** A temperature probe is fixed on a wall of the canopy. This measures the air temperature and regulates the delivered heat to match the “set air temperature”. Charts are available that suggest the air temperature based on weight, age in days and baby covered or uncovered with clothes. But, the air temperature has to be frequently readjusted based on actual baby temperature. This mode finds limited clinical application. It may be used for preheating before baby is placed inside. In transport incubator, air mode is safer. Historically, this was used to determine the time when the baby is ready to leave the incubator.

**Advantages of incubator over RW**

Advantages in thermoregulation have been mentioned above. The incubator produces a microenvironment for the baby. Hence, handling is minimized; external environmental influences are also reduced, if the canopy is not opened repeatedly.

**Disadvantages**

1. Incubator is a deterrent to baby – parent bonding. It limits parent (mother) opportunities to hold the baby and have skin – to – skin contact.

2. Nursing a baby in an incubator needs special training – handling the baby through “iris / port holes” provided in the canopy. The port holes are elbow operated. After hand wash the personnel must not touch the outside of the incubator. Repeated opening of the incubator defeats the purpose of the isolette.

3. The incubator has many concealed parts which are not easy to clean without complete and meticulous dismantling of the machine. It takes no less than a few hours to clean and make ready for use again.

**Cost**

A good incubator would cost a minimum of 1.5 lakh rupees.

**How to buy**

The incubator must have a good humidification system that can be independently regulated. (Not passive evaporation of water when heating occurs).

**Regular maintenance, spare accessories, cleaning and sterilization**

Principles of maintenance are as for RW

The incubator must be completely dismantled for cleaning (between babies and once a week, even if the same baby is admitted). Often blood stained needles, cotton balls, secretions fall into the chamber below the visible baby bed and canopy.

Air filters must be cleaned every three months (vacuum) and replaced if very dirty.
The humidifier chamber is a source of infection (wet always). It must be emptied and kept dry, when not in use. In the past, some units used to add disinfectants (acetoacetic acid – vinegar) to the water used for humidification.

Rough handling can damage the canopy. The transparent surface must not be cleaned by an alcohol based solution.

“New” developments

1. Good incubators have a double walled canopy. This minimizes the influence of environmental temperatures on the baby.

2. Weighing machine incorporated to take weight of the baby without disturbing the baby.

3. Both, incubator and RW measure abdominal temperature. Cool peripheries (cold stress) can be missed. Newer machines have an additional thermistor probe for feet.

General principles for incubator and RW

1. Clothing: Babies should not be nursed naked unless they need to be closely watched eg for respiratory distress, abnormal movements etc. Good cover like 2 layers of cotton clothes, caps and socks will optimize temperature.

2. Control environmental (NICU / nursery) temperature preferably not < 20 C.

3. Minimize handling

4. Early feeding

Points to Remember

- Effective use of phototherapy has drastically reduced the need for exchange transfusion.

- Overhead radiant warmer and incubators have revolutionised the management and prevention of hypothermia in infants.

References


CT BRAIN - THE RING LESIONS-2

* Vijayalakshmi G  
** Elavarasu E  
** Chirtrarasan P  
*** Venkatesan MD

In the last issue we saw a few facts pertaining to the tuberculous ring lesion. In this issue, we will examine the neurocysticercosis (NCC) ring which we mentioned as the commonest lesion encountered. The NCC ring goes through a series of changes that are reflected in CT and MRI. While the cyst may remain static for a variable period of time it usually progresses to a quiescent state, but the path towards this gives rise to a wide variety of clinical symptoms and signs that brings the patient to you.

The usual intermediate host is the pig. Eggs of Taenia solium are eaten by pigs through fodder contaminated with human feces. Once inside the intestinal tract, the eggs lose their protective coat and form oncospheres. These can pierce the intestinal wall and reach the tissues where they progress to the larval stage. These larvae in improperly cooked pork are consumed by man. The larvae then develop into mature worms in the intestine and periodically discharge eggs.

Human NCC and tissue cysticercosis are the result of man ingesting the eggs and becoming the intermediate host. The oncospheres or the cysticerci reach the various parts of the body just as in the pig. They are of special concern if they reach the brain or eye.

Once in the tissue they go through a series of changes that are reflected in the CT and MRI images. These appearances also correlate with clinical presentation and treatment options.

When the cysticerci lodge in the brain they are in the vesicular stage consisting of a small bag of clear fluid with the scolex within it. The membranous wall is not made out as it is very thin. They are commonly seen in the cerebral cortex and basal ganglia region as these areas are very vascular, but this is not the rule. They measure just about a centimeter. This stage lasts for a variable period of time, often many years.

At some point of time, the larva dies. When the larva dies the clear fluid is replaced by cloudy or turbid fluid. This is the symptomatic stage. In CT, both the vesicular and colloidal stages will reveal a hypodense centre. The larva may sometimes be seen as an internal nodule. What differentiates the two is the presence of an enhancing white ring and surrounding edema in the colloidal stage. This is a manifestation of host response which is known to be more often severe in children and young women than in adults.

In MRI, the vesicular stage is seen as cystic lesions isointense to CSF. (Grey in T1 and white in T2). The scolex is seen as a small solid nodule. This is the only feature that is pathognomonic of NCC. In the colloidal stage the scolex is degenerating and there is no well-defined nodule.
The lesion may also be hyperintense to CSF due to presence of protein and debris. So, NCC appears just like the tuberculous granulomatous ring with surrounding inflammatory edema.

Subsequently the scolex degenerates, being reduced to few granules. This is the granular stage. It may show ring or discoid enhancement. Finally the remnants of the parasite and
inflammation persist as nodular calcification which are best seen in CT. The edema disappears but surrounding hypodense gliotic changes may continue as an epileptogenic focus.

When NCC occurs in the cisterns they tend to grow large because of the lack of restraining effect of the brain parenchyma. The racemose variety occurs in the basal cisterns and ventricles. In this serious type, there is an abnormal proliferation of membranes though the scolex is dead. Cysticerci in the cisterns can also cause meningitis leading to hydrocephalus. The uninflamed vesicles in the cisterns are of the same density as normal CSF and therefore not obvious. MRI is useful in such cases and for spinal NCC.

Considering other parasites, the hydatid cyst is rare in the brain and is seen as a large cyst. There is no surrounding edema and no calcification, though there can be a significant mass effect.

Another important ring lesion is cerebral metastases. They can be single or multiple, seen more often at the grey-white matter junction and are accompanied by severe edema. These features with the history of malignancy elsewhere point to the diagnosis. Gliomas can also be seen as a single cystic lesion with an enhancing rim.

Time and again, we have always stressed the importance of correlating clinical findings with radiological appearances. The presence of tuberculosis or malignancy elsewhere in the body helps in diagnosis. But when faced with the only complaint of new-onset seizures and a ring lesion it is commonly NCC. Imaging also shows the number of lesions and the severity of host response which is required for deciding on the addition of steroids or mannitol to reduce Intra cranial tension (ICT).
DIAPER DERMATITIS

* Anandan V

Abstract: Diaper dermatitis is a common problem seen globally. There are still many areas which are not clear about this condition and research is under progress to understand these issues. The etiology is multifactorial including genetic predisposition, hydration, maceration and super added infection with bacterial and fungal organisms. Various diseases can also predispose to Diaper dermatitis which has been elaborated in the article. Treatment includes a combination of antibiotic, anticandidial and a steroidal preparation. Prognosis is usually guarded

Key words: Diaper dermatitis, Tidemark dermatitis, Jacquets dermatitis

Diaper (napkin) dermatitis includes all eruptions that occur in the area covered by the diaper. It was Jacquet in 1905 who made the first true description of diaper dermatitis. Although Parrott described a lesion in diaper area in 1887, it was in 1915 Zahorsky described the frequency of diaper eruption associated with an “ammoniacal” smelling diaper. Earlier diaper dermatitis had an incidence of 20 – 50% and recently with the advent of newer diapering practices mainly with the introduction of disposable diapers with super absorbent gel centers, incidence has dropped considerably. Disposable diapers were extensively used in 1960s and have become increasingly refined.

A number of causes have been identified for diaper dermatitis till date.


Of all these causes primary irritant napkin dermatitis is the most common which is going to be discussed here.

Etiopathogenesis

The etiology is not the same in all cases of diaper dermatitis and it has been found that a combination of factors is responsible for diaper dermatitis.
A) Water: Maceration of stratum corneum by occluded water appears to be the most important predisposing factor\textsuperscript{5} which in turn increases transepidermal permeability\textsuperscript{5-7}.

B) Friction: Friction between the fabric and the skin produces initial breach of the stratum corneum and predisposes to other factors to act upon to cause diaper dermatitis.

C) Urine and feces: The role of urine in the production of diaper dermatitis is highly debatable. It has been shown that urine containing various concentrations of ammonia acting upon already macerated skin can induce diaper dermatitis. It has been reported that urine whose pH is greater than 8.0 will induce inflammatory response whereas urine of pH of 5 to 8 will not\textsuperscript{8}.

It was Cooke in 1921 who identified Bacterium ammonia genes from the feces (now shown to be Proteus organism) playing a major role in the production of irritant ammoniacal diaper dermatitis\textsuperscript{9}.

It has been shown that infant’s feces contains substantial amounts of pancreatic protease and lipases and similar enzymes appear to be produced within the gut by variety of bacteria, and these fecal enzymes appear to be important skin irritants\textsuperscript{10}. These irritant effects may be enhanced by impaired barrier function and high pH and it has been found that fecal pH is high in infants fed with cow’s milk\textsuperscript{11}.

d) Microorganisms: Although it has been claimed that bacterial infections play an important role in the common primary irritant napkin dermatitis, studies have failed to prove it. On the other hand evidence for an etiological role for Candida albicans seems stronger. There appears to be a good correlation between the severity of primary irritant napkin dermatitis and the level of Candida albicans in the feces\textsuperscript{12}.

The pathogenesis of irritant diaper dermatitis could be depicted in a simple way for better understanding as follows (Fig.1).

\begin{center}
\textbf{Fig.1. Pathogenesis of diaper dermatitis}
\end{center}
The histological picture is that of mild epidermal spongiosis and mild inflammatory changes in the dermis.

**Clinical features**

The onset of diaper dermatitis is most often during 3 to 12 weeks of age with a peak prevalence between the 7 to 12 months. It has been reported in older children and adults who are incontinent of urine.

Diaper dermatitis comprises confluent erythema of the convex surfaces in contact with the napkin (i.e.) buttocks, the genitalia, the lower abdomen, pubic area and the upper thighs sparing the groin flexors.

“Tidemark dermatitis” is that one which occurs over the margins of the diaper area. Occasionally an erosive form in which shallow, round ulcers with raised crater like edges are seen which is known as “Jacquets dermatitis”. In both sexes, involvement of genitalia may lead to dysuria and acute retention of urine. Several clinical variants of diaper dermatitis have been reported which includes confluent erythema with marginal pustules, the so called satellite lesions reflects intense proliferation of Candida albicans.

The other variants are psoriasiform, herpetiform, nodular form and expanding nummular form. Whatever may be the presentation it heals with post inflammatory hypo pigmentation.

**Differential diagnosis**

Many a conditions mimic diaper dermatitis. It is worth while to remember neonatal candidiasis, congenital syphilis, zinc deficiency, multiple carboxylase deficiency, Langerhan’s cell histiocytosis, dermatophytosis, primary herpes simplex infection, primary or acquired immunodeficiency as differential diagnosis.

**Treatment**

Treatment not only involves specific measures but also includes attention towards napkins which comprises of a) Usage of good quality disposable napkins, b) Frequent changes of napkins, c) Care of the napkins which includes the usage of benzalkonium chloride during rinsing, d) Machine washing with tumble drying is recommended as it leaves the napkins softer and therefore less liable to chafe, e) Usage of moth balls during storage is strongly discouraged since it can cause hemolytic anemia, f) Marking inks to be strictly avoided since it can cause methemoglobinemia.

Specific therapy includes attention to the skin of the napkin area in the form of a) Daily bath, b) Application of water repellant emollient at each napkin change, c) Discouraging the use of talc’s.

Specific medication like 1% hydrocortisone in an ointment base applied twice daily is recommended.

Since Candida albicans plays a major role in the pathogenesis, a combination of a steroid, antifungal and antibacterial ointment can be used with great success.

**Prognosis**

Napkin dermatitis resolves when napkins are no longer worn; but napkin dermatitis may be a first sign of psoriasis and atopic dermatitis. Hence one has to be cautious not to give too optimistic a prognosis to parents.

**Future trends**

Yamamoto of Japan has shown that cotton diapers with a diagonal weave had a better effect than plain weave diapers for preventing diaper dermatitis.

Diapers with cellulose centers with an intricate wicking system prevents back flow and can hold 80 times its weight so that the skin is kept dry.
Use of diapers with breathable outer sheets has shown a reduction in candidial diaper dermatitis\textsuperscript{17}.

It is understood that primary attention towards the care of napkins and the skin of the napkin area can reduce the incidence of primary irritant napkin dermatitis to a great extent.

**Points to remember**

- **Rash involves only the convex surfaces sparing the flexures.**
- **Combination therapy is more successful.**
- **Diaper dermatitis could be forme fruste of Psoriasis and Atopic dermatitis, hence the prognosis should be guarded.**

**References**


**BOUQUET**

Congratulations to Dr. Uday Bodhankar for being nominated to the Governing Management Council of Maharashtra University of Health sciences for five yers.