Prevention of endotracheal tube related complications in ICUs

DM Seminar

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Outline of discussion

- Classify & List Complications
- Risk factors
- Preventive aspects
- Evidence for practice

- RICU practice

Complications caused by Endotracheal tubes

When ETT is in place

- Malposition
- ETT obstruction
- Cuff rupture
- Aspiration and Ventilator associated pneumonia
- VAT and sinusitis
- Laryngeal and tracheal injury

After extubation

- Tracheal stenosis
- Tracheomalacia
- OFTP
- Vocal cord dysfunction
- Laryngeal edema
- Laryngeal synechiae
- Tracheo esophageal fistula

Divatia JV, et al. Indian J. Anaesth.2005;49(4):308-318
John L Stauffer, et al. Respir Care 1999;44(7):828-843]

ET tube malposition

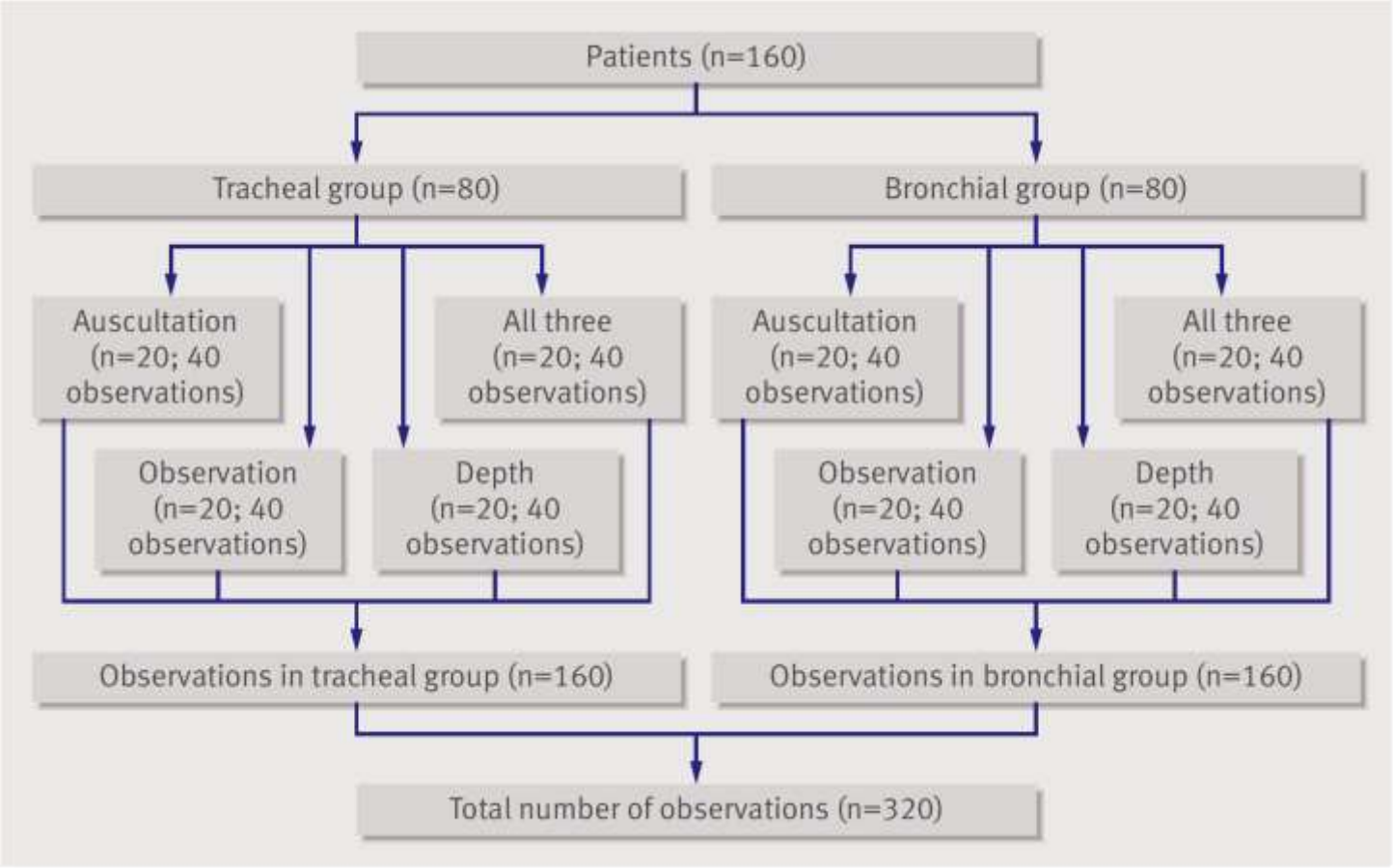
2 types

- Endobronchial migration
- Accidental extubation

In case of clinical suspicion of distal migration

- Auscultation for intensity of breath sounds
- Assessment of depth of ETT insertion
- Chest radiograph for position of ETT tip
  - Ideally 5cm above carina or midway between upper end of clavicle & carina
- Ultrasonography
- Flexible scope intubation

- Prospective randomised blinded study to determine which bedside method of detecting endobronchial intubation in adults with the highest sensitivity and specificity
- N=160 adult pts undergoing surgery
- 8 groups
- In each pt, first year resident and experienced anaesthetist were randomly assigned to independently perform any of the four test



Sitzwohl C, et al. BMJ. 2010;341:c5943

Tube position and diagnosis	Auscultation	Observation	Depth	All three
Endobronchial position:				
Correct diagnosis	26	17	35	40
Incorrect diagnosis	14	23	5	0
Tracheal position:				
Correct diagnosis	37	36	39	38
Incorrect diagnosis	3	4	1	2
Odds ratio (95% CI)†	10.5 (2.3 to 47.5), P=0.002	19.9 (4.5 to 88.5), P<0.001	3.2 (0.6 to 17.0), P=0.18	1

*Bilateral auscultation of chest; observation of symmetrical chest movements; checking cm scale (depth); or combination of all three.
†Odds ratio to predict incorrect tube position according to bedside test with "all three" as baseline category from logistic regression model with 95% confidence intervals calculated from robust standard errors to allow for correlation within patients.

	Auscultation	Observation	Depth	All three
Sensitivity† (95% CI)	65 (49 to 81)	43 (25 to 60)	88 (75 to 100)	100‡
Specificity (95% CI)	93 (84 to 100)	90 (81 to 100)	98 (93 to 100.0)	95 (88 to 100)

Sitzwohl C, et al. BMJ. 2010;341:c5943

Table 5 | Mean (SD) correct insertion depth (cm) and insertion depth during endobronchial intubation of endotracheal tube measured at incisors in women and men

	Women	Men
Tube in correct tracheal position*	21.3 (1.2)	22.7 (1.3)†
Tube in incorrect bronchial position‡	25.6 (1.7)	27.1 (2.1)†

*Insertion depth measured in 160 patients after correct placement of tube 2.5-4 cm above carina.
†P<0.05 compared with women.
‡Insertion depth measured in 80 patients after placement of tube in right mainstem bronchus.

- With the usual recommended insertion depth of 21 cm in women and 23 cm in men, the distal tip of the tube was less than 2.5 cm away from the carina in 20% (24/118) of women and 18% (7/42) of men
- An insertion depth of 20 cm in women and 22 cm in men would thus have provided correct positioning in all the patients

Sitzwohl C, et al. BMJ. 2010;341:c5943

Auscultation versus Ultrasound to determine Endotracheal *versus* Bronchial Intubation

- prospective, randomized, double-blinded, crossover trial compared the accuracy of detecting bronchial intubation between point-of-care ultrasound and auscultation in 42 adult subjects
- 3 arms : tracheal, RMB, LMB

- After ETT was placed, auscultation followed by USG (tracheal dilation and pleural sliding sign) was done by different anaesthetists who were blinded

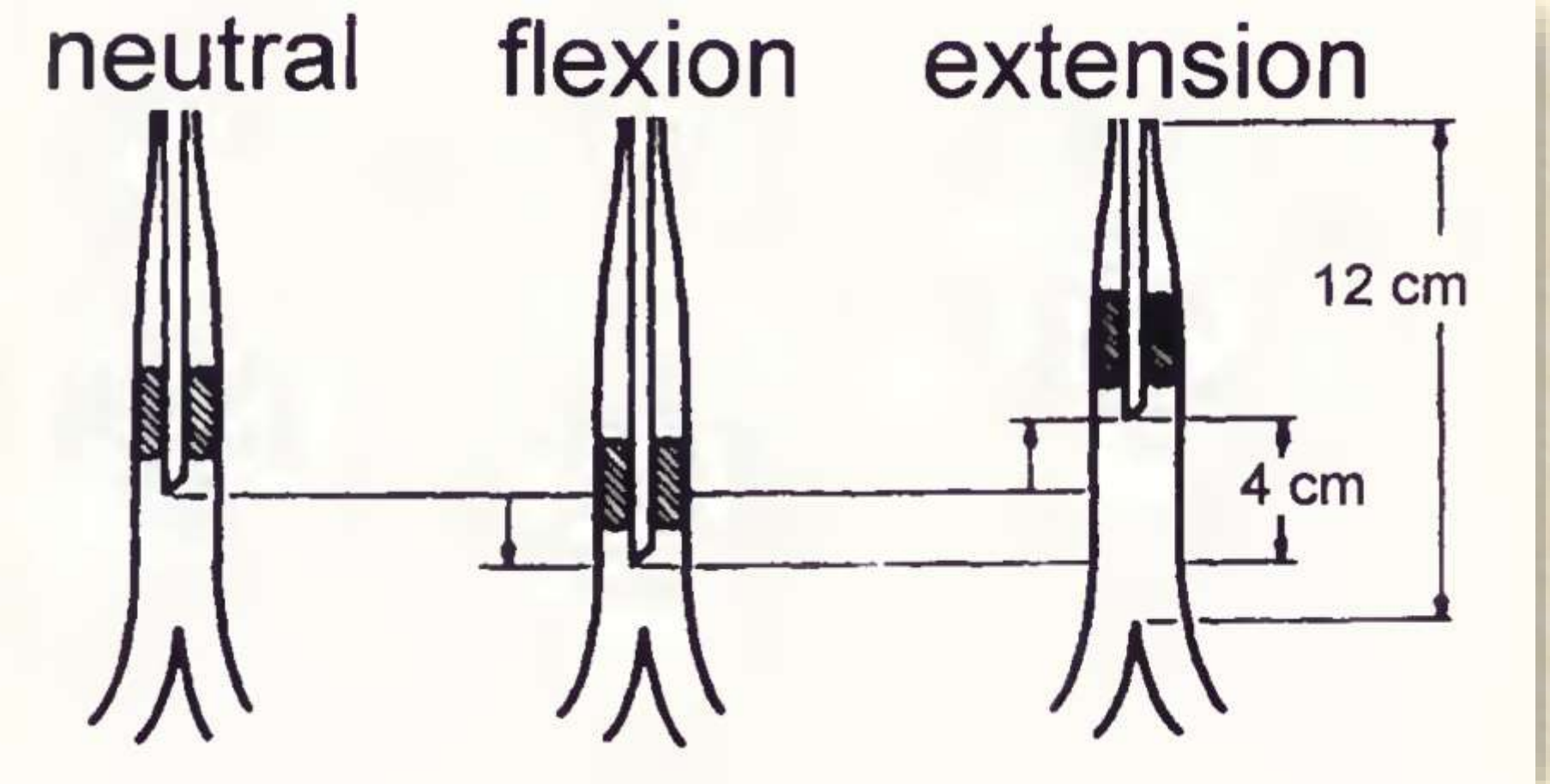
Davinder Ramsingh,et al. Anesthesiology 2016; 124:1012-20

Method	Sensitivity	Specificity
Auscultation	66% (0.39 to 0.87)	59% (0.39 to 0.77)
Ultrasonography	**93%** (0.66 to 0.99)	**96%** (0.79 to 1)

- Identification of tracheal *versus* bronchial intubation was 62% (26 of 42) in the auscultation group and **95%** (40 of 42) in the ultrasound group (*P* = 0.0005) (CI for difference, 0.15 to 0.52)

Davinder Ramsingh,et al. Anesthesiology 2016; 124:1012-20

Movement of cuff with head position



Securing the airway

- different means of securing ETT
  - Adhesive tapes
  - Twill/cotton tapes
  - Gauge tapes
  - Commercial ETT holders

Best practice in stabilisation of oral endotracheal tubes: a systematic review

- To identify and analyse the best available evidence on ETT stabilisation to determine which stabilisation method resulted in reduced tube displacement and the least amount of unplanned or accidental extubations
- Following methods: cotton/twill tape, gauge, adhesive tapes, commercial holders
- Primary outcome was incidence of ETT displacement, accidental or unplanned extubation, facial skin or lip breakdown, 7 studies were included

Gardner A, et al. Aust Crit Care. 2005;18(4):158, 160

- amount of ETT displacement was 0.6cm less (CI=0.4-0.9) if a commercially manufactured device was used (z=5.07, p=<0.001)

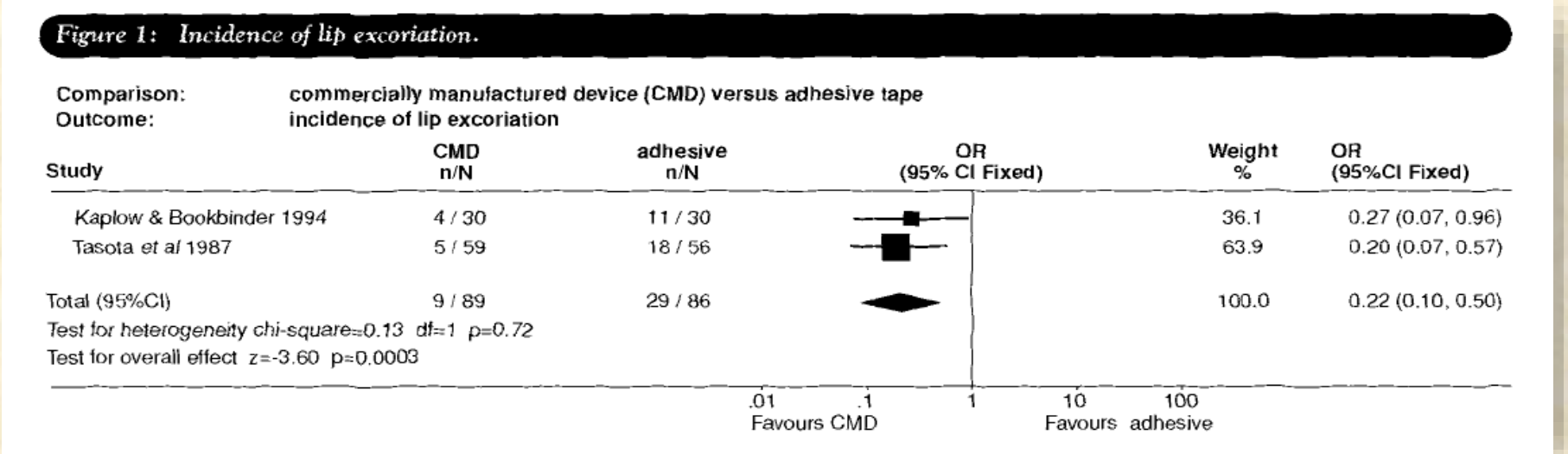


Figure 1: Incidence of lip excoriation.

Comparison: commercially manufactured device (CMD) versus adhesive tape
Outcome: incidence of lip excoriation

Study	CMD n/N	adhesive n/N	OR (95% CI Fixed)	Weight %	OR (95%CI Fixed)
Kaplow & Bookbinder 1994	4 / 30	11 / 30		36.1	0.27 (0.07, 0.96)
Tasota *et al* 1987	5 / 59	18 / 56		63.9	0.20 (0.07, 0.57)
Total (95%CI)	9 / 89	29 / 86		100.0	0.22 (0.10, 0.50)

Test for heterogeneity chi-square=0.13 df=1 p=0.72
Test for overall effect z=-3.60 p=0.0003

.01 .1 1 10 100
Favours CMD Favours adhesive

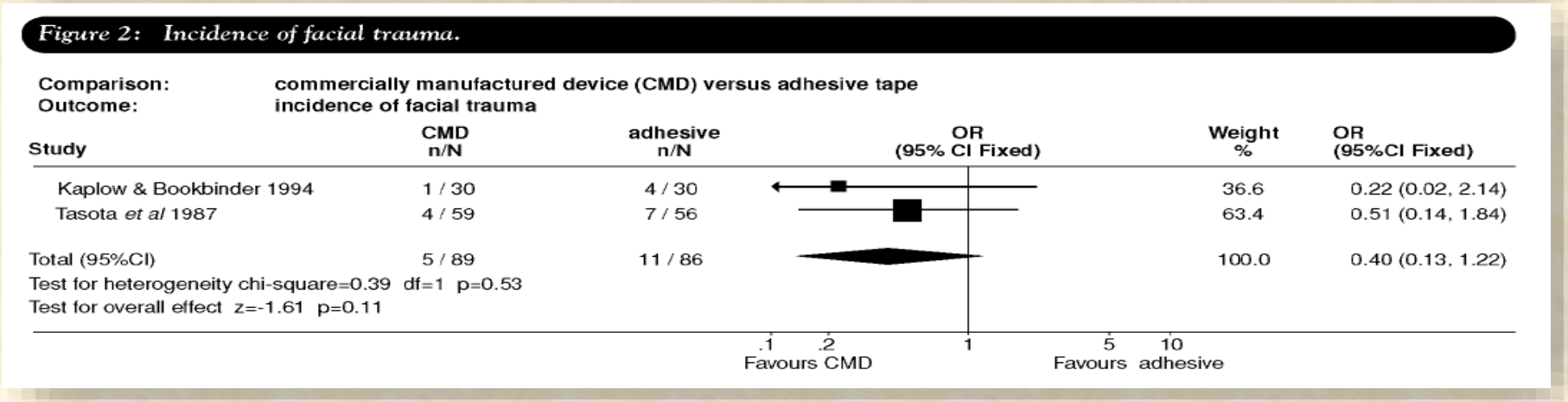


Figure 2: Incidence of facial trauma.

Comparison: commercially manufactured device (CMD) versus adhesive tape
Outcome: incidence of facial trauma

Study	CMD n/N	adhesive n/N	OR (95% CI Fixed)	Weight %	OR (95%CI Fixed)
Kaplow & Bookbinder 1994	1 / 30	4 / 30		36.6	0.22 (0.02, 2.14)
Tasota *et al* 1987	4 / 59	7 / 56		63.4	0.51 (0.14, 1.84)
Total (95%CI)	5 / 89	11 / 86		100.0	0.40 (0.13, 1.22)

Test for heterogeneity chi-square=0.39 df=1 p=0.53
Test for overall effect z=-1.61 p=0.11

.1 .2 1 5 10
Favours CMD Favours adhesive

Gardner A, et al. Aust Crit Care. 2005;18(4):158, 160

- Only one RCT was included
- Heterogenity of data
- Sample size were small

- Currently, there is insufficient information to make any recommendations regarding clinical practice of any device for securing ETT
- But securing the ETT is a standard of care and should be routinely carried out in all ventilated patients to avoid displacements and trauma to the airway

Gardner A, et al. Aust Crit Care. 2005;18(4):158, 160

Assessment of ETT position

- position of the ETT at the level of the incisors should be formally checked every shift at minimum and after turning and transport
- Transport of such patients to be kept minimum
- Routine daily chest radiographs to check ETT position are not necessary and there are evidences against it
- Chest radiographs should be done if ETT migration is suspected on clinical examination

Krivopal M, et al. Chest. 2003;123(5):1607
Gershengorn HB, et al. JAMA Netw Open. 2018;1(4):e181119

Prevention of endobronchial intubation

- ETT position to be made note of q8h & should generally be maintained to a depth of
  - **20 to 21 cm** in women
  - **22 to 23 cm** in men
- Adequate fixation of ET tube
- Avoid frequent neck flexion
- Chest radiography(done for other indication)
- Bedside ultrasound monitoring can provide an accurate assessment of ETT depth and is superior to auscultation to rule out endobronchial intubation

Unplanned / accidental extubation

- Occurs in 3-12% of intubated patients (61% were agitated)
- Less common in nasally intubated patients
- Preventive strategies
  - Strong fixation of ETT at right position
  - Adequate sedation of agitated/ delirious patients
  - Physical restrainment if needed
  - daily reassessment of the possibility of weaning from the ventilator
  - Special nursing attention to orally intubated patients
  - Avoid frequent neck extension

Chang LY, et al. Am J Crit Care. 2008;17(5):408
Boulain T, et al. Am J Respir Crit Care Med. 1998;157(4 Pt 1):1131

Prevention of ET tube obstruction

- Airway suctioning of secretions
- Adequate humidification of inspired gases to prevent inspissation of secretions
- Avoid kinking of ET tube by using flexible connectors(catheter mounts)
- Frequent replacement of HME filters
- Usage of ET tube with murphy's eye
- Ensure the cuff is not herniating into the lumen of the tube by checking prior to intubation

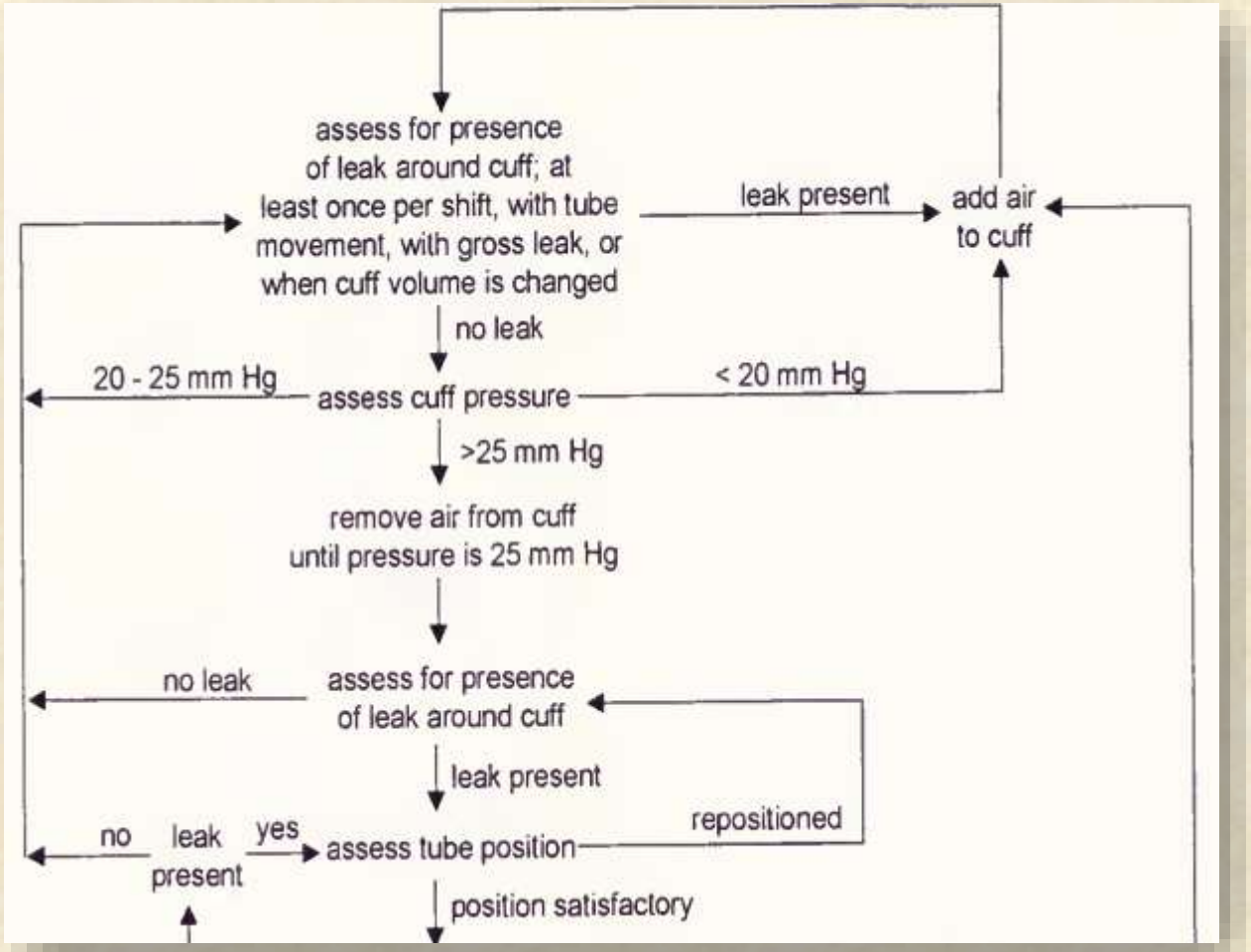
Dorsch JA, et al. Understanding anaesthesia equipment: construction, care and complications, 3rd ed. Williams and Wilkins, 1994

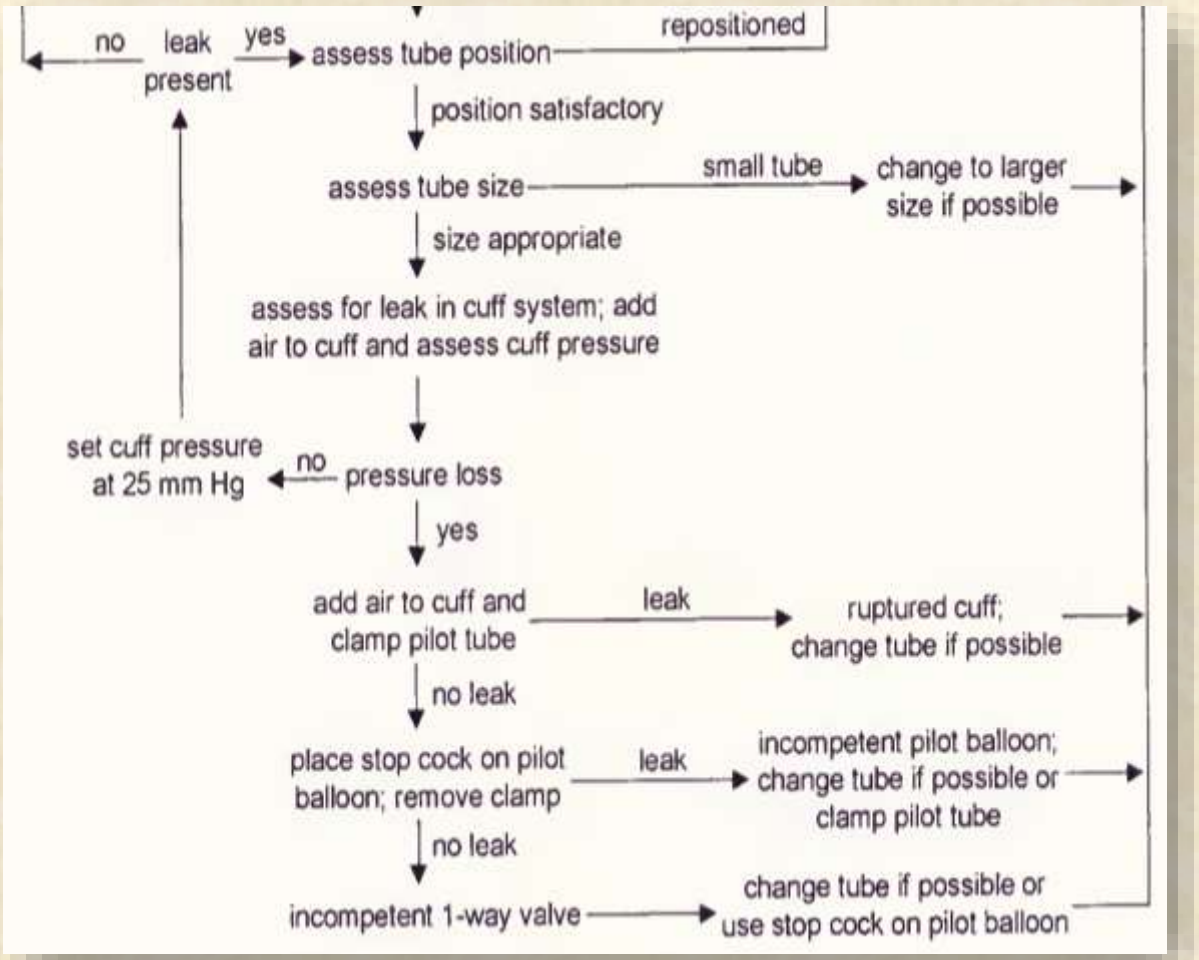
Prevention of endotracheal cuff leak

- Incidence of endotracheal cuff leaks in patients admitted to the ICU is 6 to 11 percent
- Ensuring there are no structural defect in the pilot tube or balloon before intubation
- Routine monitoring of cuff pressures
- Using an optimal size of ET tube
- Avoiding cephalad migration of cuff
- Ensure pilot tubes are not bitten by the pts
- Precautions taken to avoid cuff trauma in difficult intubation

El-Orbany M, et al. Anesth Analg. 2013 Aug;117(2):428-34

Not all cuff leaks need ET replacement!





- When an ETT is removed because of an alleged "massive air leak," a defect in the ETT cuff is found in only in a minority of cases, and tube malposition is implicated as the most likely cause of the apparent leak.''

El-Orbany M, et al. Anesth Analg. 2013 Aug;117(2):428-34

Prevention of cuff leaks

- Selection of appropriate size of the ET tube
  - Formulas for children
  - Women: 7.0, 7.5
  - Men: 7.5, 8.0
- Proper positioning of patient
- Ensure that the cuff is working optimally before intubation

Ventilator associated pneumonia

- Host
- Patient
- Endotracheal tube

Subglottic Secretion Drainage and Outcomes

- systematic review and meta-analysis of the impact of subglottic secretion drainage on duration of mechanical ventilation, ICU and hospital length of stay, ventilator-associated events, mortality,
- 21 RCTs were assessed & 17 eligible trials with a total of 3,369 patients were included
- Included adults age >18yrs and those in whom expected days of ventilation is more than 48hrs

Caroff DA, et al. Crit Care Med. 2016;44(4):830

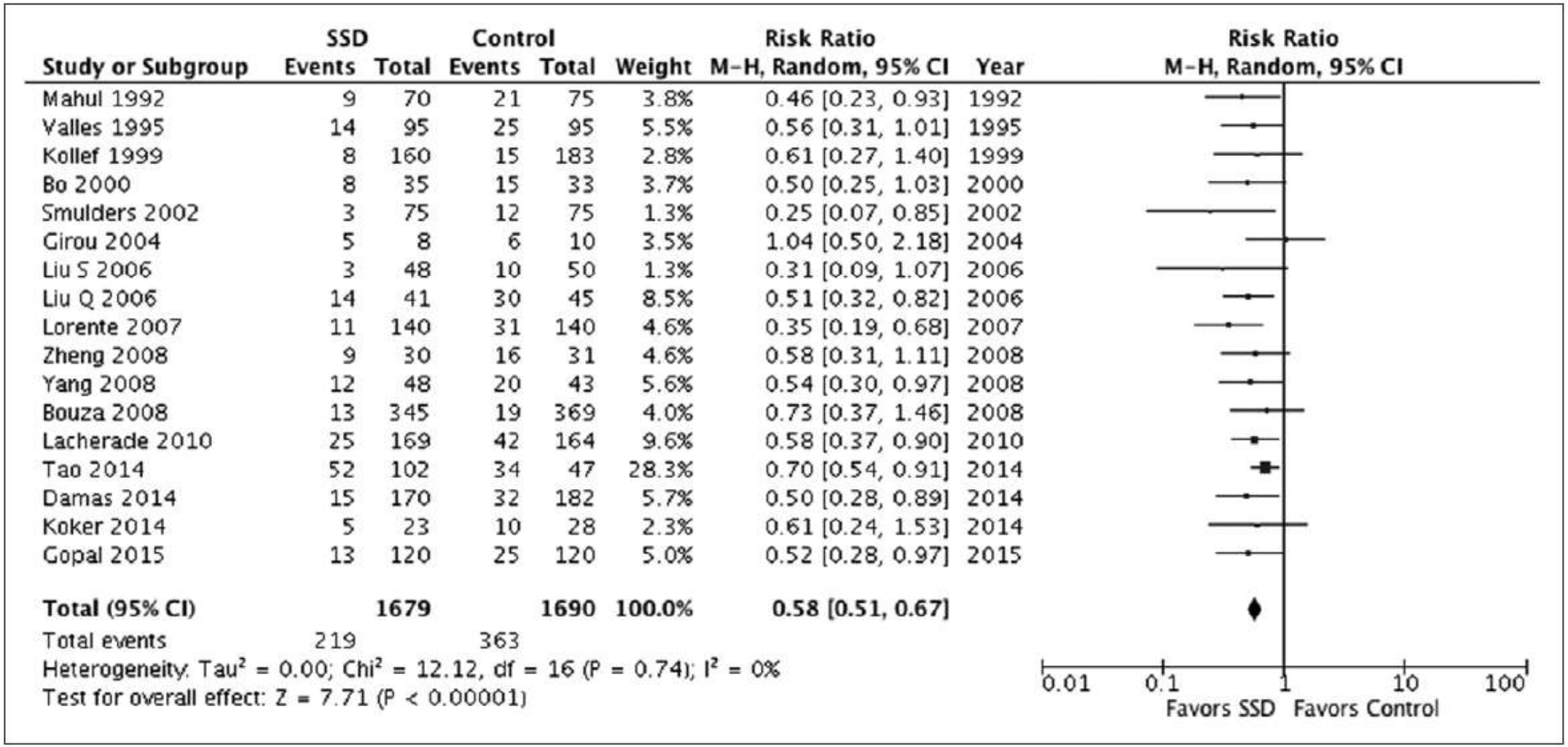


Figure 2. Ventilator-associated pneumonia in patients with subglottic secretion drainage (SSD) versus controls. M–H = Mantel-Haenszel.

- The overall RR for VAP in patients receiving SSD was 0.58 (95% CI, 0.51–0.67; $p < 0.0001$) with no heterogeneity
- Use of subglottic drainage reduced the risk of VAP from 21 to 13 percent (risk ratio 0.58, 95% CI 0.51-0.67)

Caroff DA, et al. Crit Care Med. 2016;44(4):830

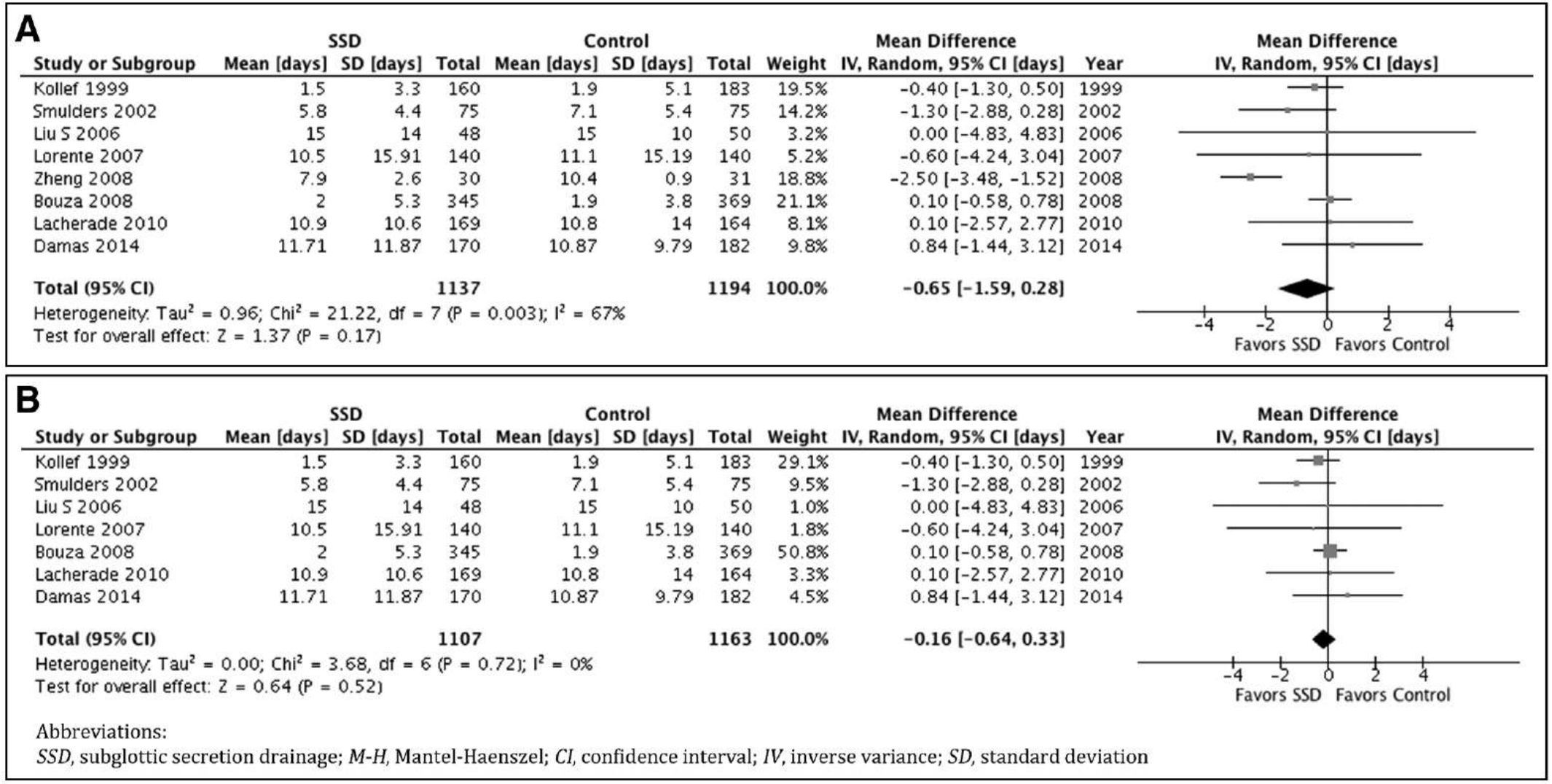


Figure 3. Duration of mechanical ventilation in patients with subglottic secretion drainage (SSD) versus controls. **A**, All studies with available mean and SD for duration of mechanical ventilation. One study (Zheng et al [36]) is an outlier relative to all other studies and leads to high heterogeneity on meta-analysis ($I^2 = 67\%$). **B**, Findings on meta-analysis after excluding Zheng et al (36) ($I^2 = 0\%$). M–H = Mantel-Haenszel, IV = inverse variance.

Caroff DA, et al. Crit Care Med. 2016;44(4):830

Study or Subgroup	SSD Events	SSD Total	Control Events	Control Total	Weight	Risk Ratio M-H, Random, 95% CI	Year
Mahul 1992	17	70	16	75	3.0%	1.14 [0.62, 2.07]	1992
Valles 1995	39	95	35	95	8.3%	1.11 [0.78, 1.59]	1995
Kollef 1999	6	160	8	183	1.0%	0.86 [0.30, 2.42]	1999
Smulders 2002	12	75	10	75	1.8%	1.20 [0.55, 2.61]	2002
Liu Q 2006	18	41	13	45	3.2%	1.52 [0.86, 2.70]	2006
Liu S 2006	5	48	11	50	1.1%	0.47 [0.18, 1.26]	2006
Lorente 2007	26	140	32	140	5.0%	0.81 [0.51, 1.29]	2007
Yang 2008	32	48	29	43	12.8%	0.99 [0.74, 1.32]	2008
Zheng 2008	8	30	12	31	1.9%	0.69 [0.33, 1.44]	2008
Bouza 2008	34	345	35	369	5.3%	1.04 [0.66, 1.63]	2008
Lacherade 2010	80	169	84	164	22.3%	0.92 [0.74, 1.15]	2010
Tao 2014	48	102	29	47	11.4%	0.76 [0.56, 1.03]	2014
Damas 2014	78	170	93	182	22.7%	0.90 [0.72, 1.11]	2014
Gopal 2015	2	120	1	120	0.2%	2.00 [0.18, 21.76]	2015
Total (95% CI)		**1613**		**1619**	**100.0%**	**0.93 [0.84, 1.03]**	
Total events	405		408				

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 9.99$, df = 13 (P = 0.69); $I^2 = 0\%$

Test for overall effect: Z = 1.31 (P = 0.19)

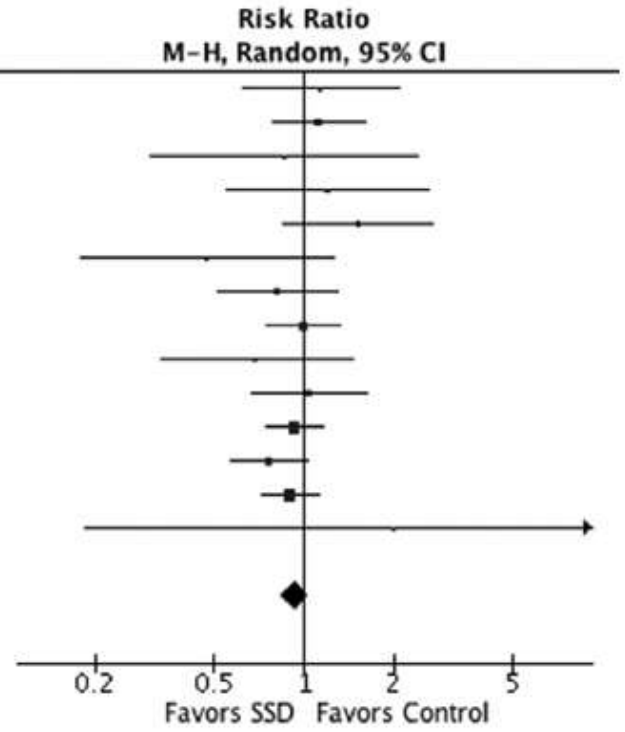


Figure 5. Mortality rates in patients with subglottic secretion drainage (SSD) versus controls. All studies that provided mortality data regardless of mortality time point were included. Analyses restricted to studies that reported ICU mortality and hospital mortality, respectively, are reported in the text. M–H = Mantel-Haenszel.

Caroff DA, et al. Crit Care Med. 2016;44(4):830

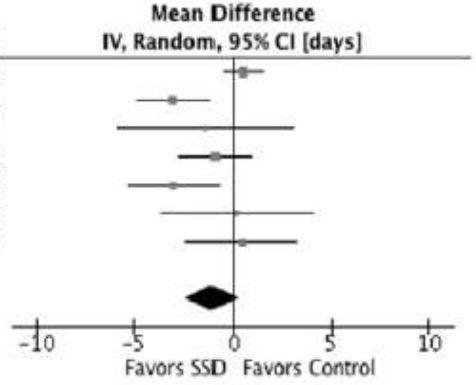
ICU Length-of-Stay

A

Study or Subgroup	SSD Mean [days]	SSD SD [days]	SSD Total	Control Mean [days]	Control SD [days]	Control Total	Weight	Mean Difference IV, Random, 95% CI [days]	Year
Kollef 1999	3.7	4.6	160	3.2	4.5	183	22.5%	0.50 [-0.47, 1.47]	1999
Smulders 2002	9.3	7.4	75	12.3	3.6	75	17.3%	-3.00 [-4.86, -1.14]	2002
Lorente 2007	14.1	17.91	140	15.5	19.93	140	6.9%	-1.40 [-5.84, 3.04]	2007
Bouza 2008	5.6	10.7	345	6.5	14.2	369	17.4%	-0.90 [-2.74, 0.94]	2008
Zheng 2008	9.3	2.9	30	12.3	5.7	31	15.0%	-3.00 [-5.26, -0.74]	2008
Lacherade 2010	15.9	14.4	169	15.7	20.4	164	8.6%	0.20 [-3.60, 4.00]	2010
Damas 2014	16.2	13.52	170	15.76	13.15	182	12.3%	0.44 [-2.35, 3.23]	2014
Total (95% CI)			**1089**			**1144**	**100.0%**	**-1.04 [-2.40, 0.33]**	

Heterogeneity: $Tau^2 = 1.92$; $Chi^2 = 16.62$, df = 6 (P = 0.01); $I^2 = 64\%$

Test for overall effect: Z = 1.49 (P = 0.14)

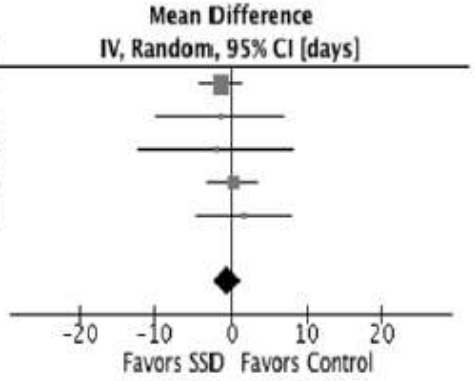


Hospital Length-of-Stay

Study or Subgroup	SSD Mean [days]	SSD SD [days]	SSD Total	Control Mean [days]	Control SD [days]	Control Total	Weight	Mean Difference IV, Random, 95% CI [days]	Year
Kollef 1999	11	11.2	160	12.4	14.2	183	48.5%	-1.40 [-4.09, 1.29]	1999
Smulders 2002	26.8	23.3	75	28.3	28.2	75	5.1%	-1.50 [-9.78, 6.78]	2002
Liu S 2006	30	31	48	32	19	50	3.4%	-2.00 [-12.23, 8.23]	2006
Bouza 2008	14	25.4	345	13.7	17.4	369	34.0%	0.30 [-2.91, 3.51]	2008
Damas 2014	34.92	32.56	170	33.27	26.36	182	9.1%	1.65 [-4.56, 7.86]	2014
Total (95% CI)			**798**			**859**	**100.0%**	**-0.57 [-2.44, 1.30]**	

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 1.26$, df = 4 (P = 0.87); $I^2 = 0\%$

Test for overall effect: Z = 0.60 (P = 0.55)



Caroff DA, et al. Crit Care Med. 2016;44(4):830

- Two out of three studies reported significantly less antibiotic usage in SSD patients
- no differences in stridor (RR, 1.58; 95% CI, 0.68–3.67; $p = 0.29$) or reintubation (RR, 0.99; 95% CI, 0.65–1.51; $p = 0.96$) rates between SSD and control groups

- Prior meta analysis showed significant decrease in VAP rates, duration of mechanical ventilation and length of ICU stay but the current study shows benefit of subglottic suction in reducing VAP rates only

Muscedere J, et al. Crit Care Med 2011; 39:1985–1991
Wang F, et al. J Trauma Acute Care Surg 2012; 72:1276–1285
Frost SA, et al. Aust Crit Care 2013; 26:180–188

Silver-coated endotracheal tube : NASCENT trial

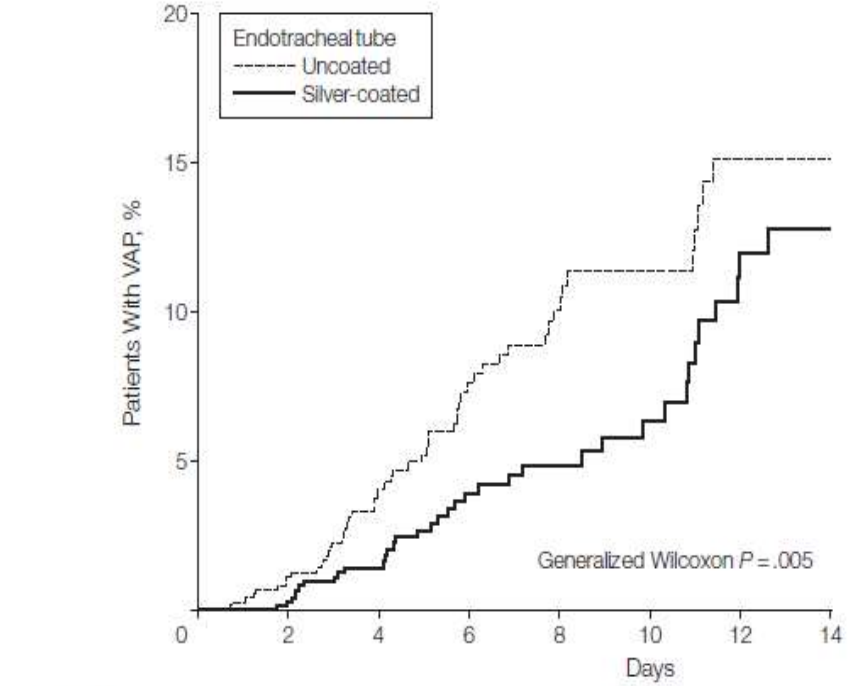
- prospective, randomized, single-blind, trial to determine whether a silver-coated endotracheal tube would reduce the incidence of microbiologically confirmed VAP when compared to uncoated tubes
- N=2003 adult patients expected to require ventilation more than 24 hrs were included
- Primary outcome was VAP incidence, other outcomes were time to VAP onset, length of intubation and duration of ICU and hospital stay, mortality and adverse events
- 1:1 ratio, high volume low pressure tubes with and without silver coating

Kollef MH,et al. JAMA. 2008;300(7):805

Table 2. Incidence of Microbiologically Confirmed Ventilator-Associated Pneumonia (VAP)[a]

	Evaluable Patients With VAP, No./Total (%) [95% CI]			
	Silver-Coated Tube	Uncoated Tube	RR Reduction, % (95% CI)	*P* Value
VAP at any time				
Intubated ≥24 h	37/766 (4.8) [3.4-6.6]	56/743 (7.5) [5.7-9.7]	35.9 (3.6-69.0)	.03
All intubated	37/968 (3.8) [2.7-5.2]	56/964 (5.8) [4.4-7.5]	34.2 (1.2-67.9)	.04
VAP within 10 d of intubation				
Intubated ≥24 h	27/766 (3.5) [2.3-5.1]	50/743 (6.7) [5.0-8.8]	47.6 (14.6-81.9)	.005
All intubated	27/968 (2.8) (1.9-4.0)	50/964 (5.2) (3.9-6.8)	46.2 (12.6-81.1)	.007
Microbiology[b]				
Staphylococcus aureus	9	16		
Methicillin-resistant *S aureus*	3	7		
Pseudomonas aeruginosa	8	11		
Enterobacteriaceae	10	5		
Yeast	5	7		
Streptococcus species	4	7		
Haemophilus influenzae	3	3		
Acinetobacter baumannii	1	5		
Other[c]	5	17		

Figure 2. Kaplan-Meier Analyses of Occurrence of Microbiologically Confirmed Ventilator-Associated Pneumonia (VAP) in Patients Intubated for 24 Hours or Longer



Uncoated, No.								
At risk	743	718	529	359	235	157	106	75
New VAP cases	0	9	20	13	8	0	5	0
Silver-coated, No.								
At risk	766	750	565	387	264	179	124	79
New VAP cases	0	7	8	7	3	3	7	2

Kollef MH,et al. JAMA. 2008;300(7):805

Table 4. Adverse Events in All Intubated Patients

Adverse Event	Silver-Coated Tube (n = 968)		Uncoated Tube (n = 964)		*P* Value
	Events, No.	Patients, No. (%)	Events, No.	Patients, No. (%)	
Possibly related to endotracheal tube	196	122 (12.6)	149	111 (11.5)	.46
Definitely related to endotracheal tube	21	18 (1.9)	38	27 (2.8)	.17
Unanticipated	11	10 (1.0)	22	15 (1.6)	.31
Cough and other respiratory disorders	2	2 (0.2)	7	6 (0.6)	.15
Dysphagia and other gastrointestinal tract disorders	2	2 (0.2)	4	4 (0.4)	.41
Bacteremia, sepsis, and other infections	2	1 (0.1)	3	2 (0.2)	.56
Device malfunction and other procedural complications	2	2 (0.2)	1	1 (0.1)	.57
Other[a]	3	3 (0.3)	7	7 (0.7)	.20
Possibly related to intubation procedure	167	113 (11.7)	137	100 (10.4)	.36
Definitely related to intubation procedure	39	28 (2.9)	35	25 (2.6)	.69

[a] In the group receiving the silver-coated tube, other events were abnormal breath sounds (n = 1), anxiety (n = 1), and skin disorder (n = 1). In the group receiving the uncoated tube, other events were catheter-related complication (n = 1), edema (n = 1), decreased oxygen (n = 1), atrial flutter (n = 1), headache (n = 1), and acute renal failure (n = 1).

Kollef MH,et al. JAMA. 2008;300(7):805

- No between-group differences were noted in
  - Median durations of intubation(4.0 [IQR, 1.9-7.9] days [*P*=.59]
  - ICU stay (8.0 [IQR, 4.0-14.0] days [*P*=.92]
  - Hospital stay (patients intubated with the silver-coated tube for 24 hours, 16.0 [IQR, 10.0-26.0] days[*P*=.57
  - Mortality rates were 30.4% (233/766) in the group receiving the silver- coated tube and 26.6% (198/743) in the group receiving the uncoated tube (*P*=.11)

- silver-coated endotracheal tube significantly reduced the incidence of microbiologically confirmed VAP and had its greatest benefit during the peak time of VAP occurrence, without any notable adverse events

Kollef MH,et al. JAMA. 2008;300(7):805

Automatic control of tracheal tube cuff pressure in ventilated patients

- prospective, RCT to assess the efficacy of an automatic device for the continuous regulation of tracheal tube cuff pressure in preventing ventilator associated pneumonia in ICUs
- N=142 adult pts, expected to be ventilated >48 hrs
- Those with pneumonia and aspiration were excluded
- Randomised into continuous automatic regulation of cuff pressure and control group of routine care of monitoring cuff pressure q 8 h manually in 1:1 ratio to maintain pressure of 25-30cm H2O by high volume low pressure tubes
- Primary outcome: incidence of VAP

- Higher proportion of Pcuff determinations <20 cm H2O were observed in patients from the control group compared with the automatic group (*p* .001)
- The proportion of Pcuff determinations within the target of 25–30 cm H2O was higher in the automatic group compared with the control group (*p* .001)

Table 3. Other variables potentially influencing ventilator-associated pneumonia at entry or during the intensive care unit stay

	Automatic Group (n = 73)	Control Group (n = 69)	*p* Value
Previous surgery, n (%)	16 (22)	24 (35)	.14
Nasogastric tube, n (%)			.50
Large bore	72 (99)	68 (99)	
Small bore	1 (1)	1 (1)	
Enteral nutrition, n (%)	42 (58)	40 (58)	.91
Parenteral nutrition, n (%)	12 (16)	15 (22)	.56
Stress ulcer prophylaxis, n (%)	70 (96)	69 (100)	.090
Histamine H-2 blockers	30 (41)	42 (61)	
Proton-pump inhibitors	39 (53)	27 (39)	
Sucralfate	1 (1)	0 (0)	
Type of humidification, n (%)			>.99
Heated humidifier	3 (4)	2 (3)	
Heat and moisture exchanger	70 (96)	67 (97)	
Previous use of antibiotics, n (%)	50 (69)	55 (80)	.19
Registered levels of P_{cuff}, % of all determinations			<.001
<20 cm H_2O	0.7	45.3	
21–25 cm H_2O	25.8	16.8	
26–30 cm H_2O	53.5	31.5	
31–35 cm H_2O	17.1	1.2	
>35 cm H_2O	2.9	5.2	

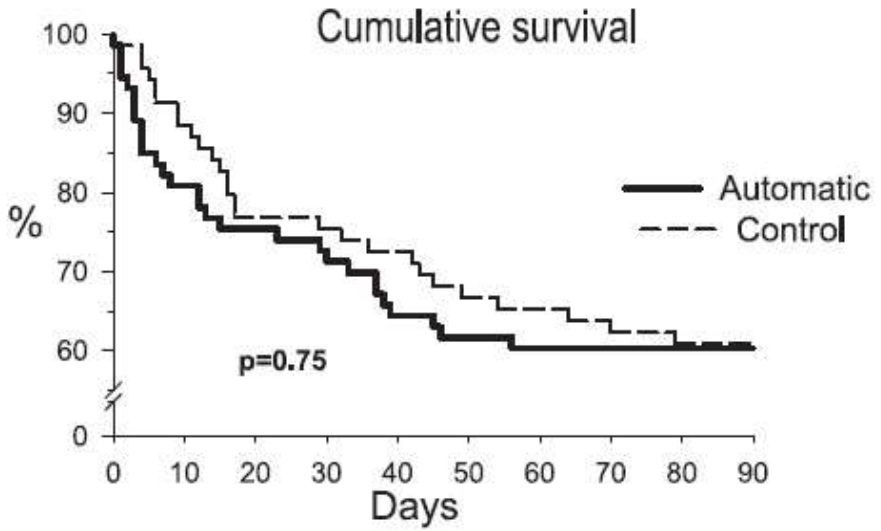


Figure 3. Kaplan-Meier curves for surviving patients within 90 days after entry into the protocol. The cumulative survival probability was similar in the two groups (log-rank test). Time denotes days after patients were entered into the study.

Table 4. Outcome variables, length of stay, and causes of death for the noninvasive ventilation and the control groups

	Automatic Group (n = 73)	Control Group (n = 69)	*p* Value
Incidence of VAP with clinical criteria, n (%)	16 (22)	20 (29)	.44
Early-onset VAP	7 (10)	10 (15)	—
Late-onset VAP	9 (12)	10 (15)	—
Days from intubation to VAP, mean ± SD	6 ± 7	5 ± 3	.56
Microbiologically confirmed VAP, n (%)	11 (15)	10 (15)	.89
Causative microorganisms, n			
Haemophilus influenzae	4	1	
Pseudomonas aeruginosa	3	1	
Methicillin-susceptible *Staphylococcus aureus*	1	2	
Enterobacter species	—	2	
Serratia species	—	1	
Klebsiella species	—	1	
Streptococcus pneumoniae	—	1	
Methicillin-resistant *S. aureus*	1	—	
Acinetobacter species	1	—	
Aspergillus fumigatus	1	1	
Severity criteria at onset of VAP, n (%)			
Bacteremia	1 (6)	1 (5)	>0.99
Pleural effusion secondary to VAP	5 (31)	4 (20)	0.70
Septic shock	5 (31)	6 (30)	0.78
Other ICU-acquired infections, n (%)			
Purulent tracheobronchitis	6 (8)	7 (10)	0.92
Urinary tract infection	3 (4)	5 (7)	0.66
Catheter-related infection	3 (4)	2 (3)	0.95
Bacteremia of unknown origin	5 (7)	3 (4)	0.78
Tracheostomy, n (%)	18 (25)	11 (16)	0.28
ICU length of stay, days, mean ± SD	13 ± 14	13 ± 14	0.88
Hospital length of stay, days, mean ± SD	30 ± 33	25 ± 20	0.28
ICU mortality, n (%)	20 (27)	16 (23)	0.70
Hospital mortality, n (%)	30 (41)	23 (33)	0.43
Causes of death within 90 days, n[a]			
Shock, multiple organ dysfunction syndrome	10	10	
Postanoxic encephalopathy	9	5	
Cardiac arrest	5	3	
Refractory hypoxemia	3	2	
Limitation of the therapeutic effort	1	3	
Not determined	2	4	

Intervention	Quality of evidence
Use noninvasive positive pressure ventilation in selected populations	High
Manage patients without sedation whenever possible	Moderate
Interrupt sedation daily	High
Assess readiness to extubate daily	High
Perform spontaneous breathing trials with sedatives turned off	High
Facilitate early mobility	Moderate
Utilize endotracheal tubes with subglottic secretion drainage ports for patients expected to require greater than 48 or 72 hours of mechanical ventilation	Moderate
Change the ventilator circuit only if visibly soiled or malfunctioning	High
Elevate the head of the bed to 30 to 45°	Low*
Selective oral or digestive decontamination	High ¶
Regular oral care with chlorhexidine	Moderate
Prophylactic probiotics	Moderate
Ultrathin polyurethane endotracheal tube cuffs	Low
Automated control of endotracheal tube cuff pressure	Low
Saline instillation before tracheal suctioning	Low
Mechanical tooth brushing	Low
Silver-coated endotracheal tubes	Moderate
Kinetic beds	Moderate
Prone positioning	Moderate
Stress ulcer prophylaxis	Moderate
Early tracheotomy	High
Monitoring residual gastric volumes	Moderate
Early parenteral nutrition	Moderate
Closed/in-line endotracheal suctioning	Moderate

SHEA/IDSA 2008 guidelines for strategies in prevention of VAP in acute critical care

Nosocomial Sinusitis

- Prospective observational study(1998)
- N=90
- Diagnosis was done by clinical + culture + CT evidence

- Risk factors included
  - nasal colonization with enteric gram-negative bacilli
  - feeding via nasoenteric tube
  - Sedation and low GCS less than 7

George DL, et al. Clin Infect Dis. 1998;27(3):463

Nasotracheal vs orotracheal intubation

- prospective, randomized, clinical trial. To compare the occurrence rate of nosocomial maxillary sinusitis and pneumonia in patients who have undergone nasotracheal vs. orotracheal intubation
- N=300 randomised into two arms in 1:1ratio
- 54 had sinusitis, 29 in the nasal group vs 25 in the oral group (p = .75, log-rank test)
- Nosocomial pneumonia in 26 patients, 17 in the nasal group vs 9 in the oral group (p = .11, log-rank test)
- multivariable analysis considering sinusitis as a time-dependent factor showed that sinusitis increased the risk of nosocomial pneumonia by 3.8
- Mean length of ICU stay was not statistically different

Holzapfel L, et al. Crit Care Med. 1993;21(8):1132

Effects of topically applied α-adrenergic agonists and corticosteroids in prevention of nosocomial maxillary sinusitis in ICU

- prospective, open-label randomized study to evaluate the efficacy of locally applied nasal decongestant agents and corticosteroids for preventing nosocomial maxillary sinusitis in mechanically ventilated patients
- N=**79**, **multiple trauma** patients expected to be ventilated > 3days
- Randomly assigned to receive either a combination of a locally applied nasal decongestant agents: 2 drops BD of xylometazoline nasal solution 0.1% x 14days and 100micro g budesonide or placebo in 1:1 ratio
- Facial trauma, coagulation disorders were excluded

Pneumatikos, et al. Intensive Care Med. 2006;32(4):532

- Classified as radiological or infective maxillary sinusitis
- RMS was detected in 53.8% of patients in the NDCA group (n = 21) and in 82.5% of those in the control group (n = 33; $p < 0.01$)
- IMS in 7.7% (n = 3) and 20% (n = 8; p = 0.11)

Period (days)	NDCA RMS	IMS	Control RMS	IMS
0–2	2	0	7	0
4–7	3	0	8	2
7–14	10	2	13	4
>14	6	1	7	2
Total	21	3	33	8

NDCA reduced RMS by 28.7% & IMS by 13.3%

- most commonly pathogens were *Acinetobacter* (32%), *Staphylococcus aureus* (21%), *Pseudomonas aeruginosa* (21%), and anaerobes (21%)
- No anaerobe micro-organisms were isolated from maxillary aspirates in patients in the NDCA group

Pneumatikos, et al. Intensive Care Med. 2006;32(4):532

Laryngeal trauma and vocal cord dysfunction

- Prospective study, n=136 patients, extubated after more than 24 h
- Fiberoptic endoscopic examination of the larynx was systemically performed within 6 h after extubation in order to record laryngeal anomalies: edema, ulceration, granulation, and abnormal vocal cord mobility
- 73% had laryngeal injuries, median duration of intubation was 3days
- Injuries were associated with duration of intubation [OR 1.11, 95% CI 1.02-1.21, P = 0.02]and absence of use of myorelaxant drugs at intubation (OR 0.13, 95% CI 0.01-0.99, P = 0.05)

TadiéJM, et al. Intensive Care Med. 2010 Jun;36(6):991-8

- 13% had stridor after extubation, lesions associated with stridor were edema (67%, P<0.01) and abnormal VC mobility (67%, P<0.01)
- Stridor was associated with duration of ventilation and emergency intubation
- Injuries commonly seen were granulation (29.4%, P = 0.02) and abnormal VC mobility (58.8%, P<0.01)

TadiéJM, et al. Intensive Care Med. 2010 Jun;36(6):991-8

Prevention of ETT in situ trauma

- Early anticipation of difficult airways
- Minimizing emergency intubations
- Use of adequate muscle relaxation during intubation
- Minimising the duration of intubation, Assessment for weaning and extubation should be carried daily

- These measure may reduce most of the ETT in situ complications and in fact may reduce the long term complications

Mechanisms of long term complications

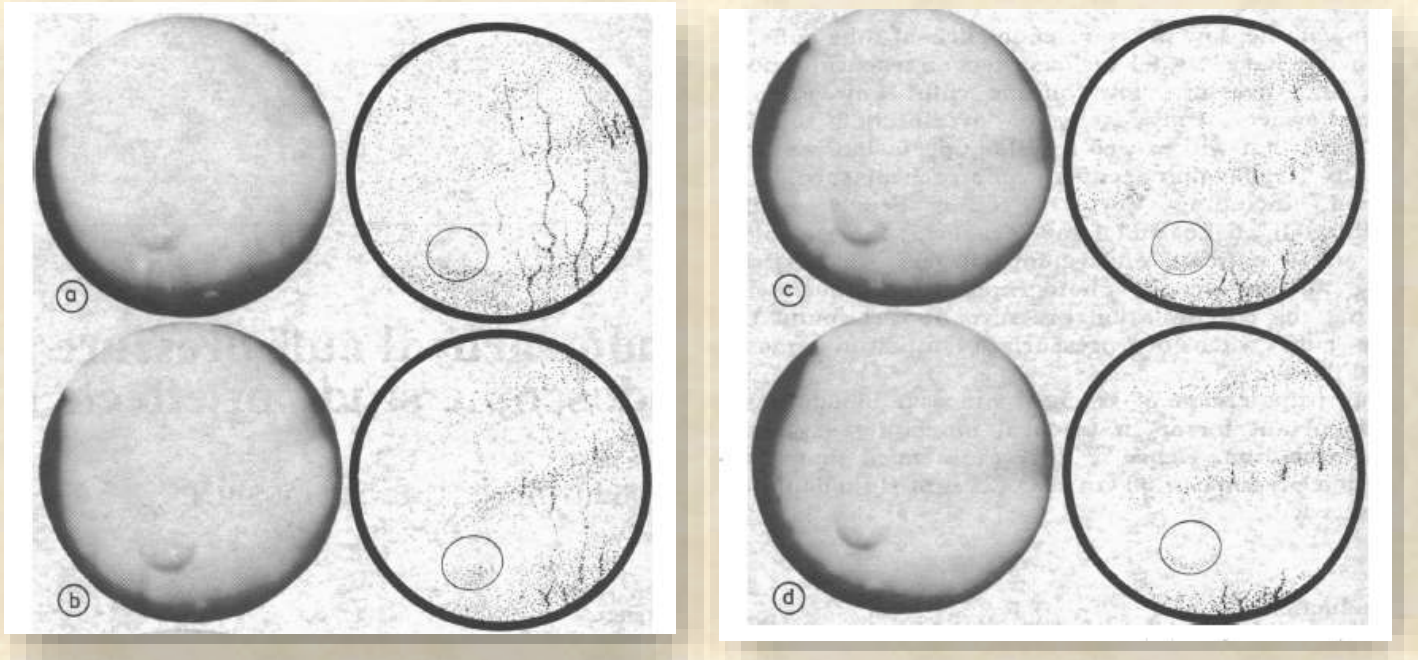
- Ischemic injury and pressure necrosis caused by inflated cuff/ET tube itself for prolonged duration
- Injuries caused due to difficult intubation

- Cicatricial healing of transmural injuries
- Abnormal communication with surrounding structures
- Loss of cartilaginous support
- Accumulation of desquamated necrotic epithelium, fibrin, clot, leucocytes

John C. Wain, et al. Chest Surg Clin N Am.2003;13:231– 246

ET cuff pressure & tracheal mucosal blood flow

- Endoscopic photographic technique to study the effects of lateral wall pressure of transparent ET tubes on mucosal vessels of trachea
- 40 adults undergoing surgery were included
- 4 types of 8.5mm ET tubes were used and randomised



Seegobin RD, et al. Br Med J (Clin Res Ed)1984;288(6422):965-968

Results

- At and above a cuff pressure of **50 cm H2O** (37 mmHg) there was clear evidence of obstruction to mucosal blood flow over the cartilagenous rings
- continuous lateral wall pressure above **30 cm water** (22 mm Hg) compromises the mucosal capillary blood flow

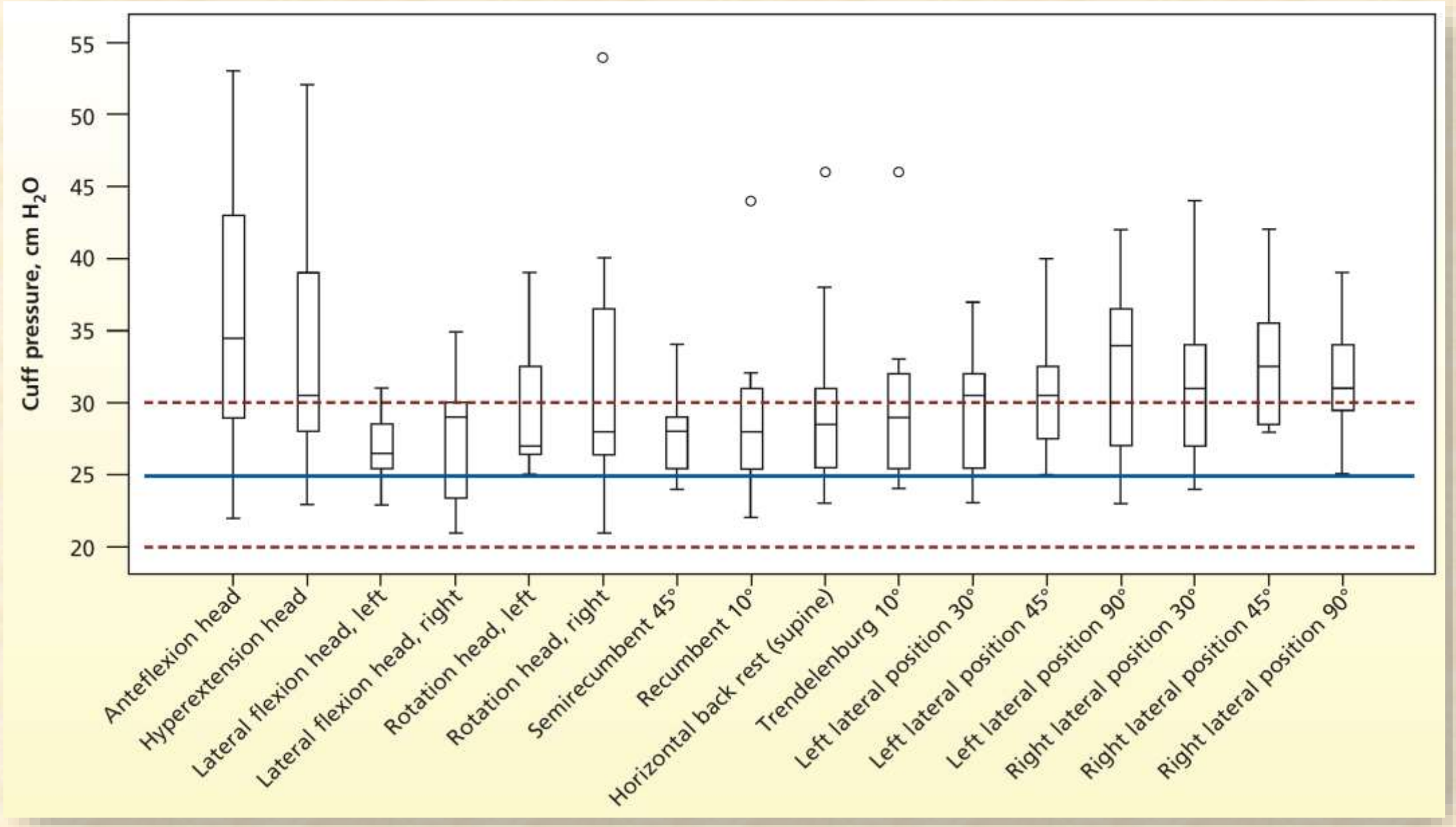
Seegobin RD, et al. Br Med J (Clin Res Ed)1984;288(6422):965-968

Does cuff pressure changes with body position?

- 12 orally intubated and sedated pts x 16 changes in head position
- Cuff pressures were noted at end expiratory hold in every position and compared with neutral head position
- Values outside the target range (20-30 cm H2O) were considered clinically relevant

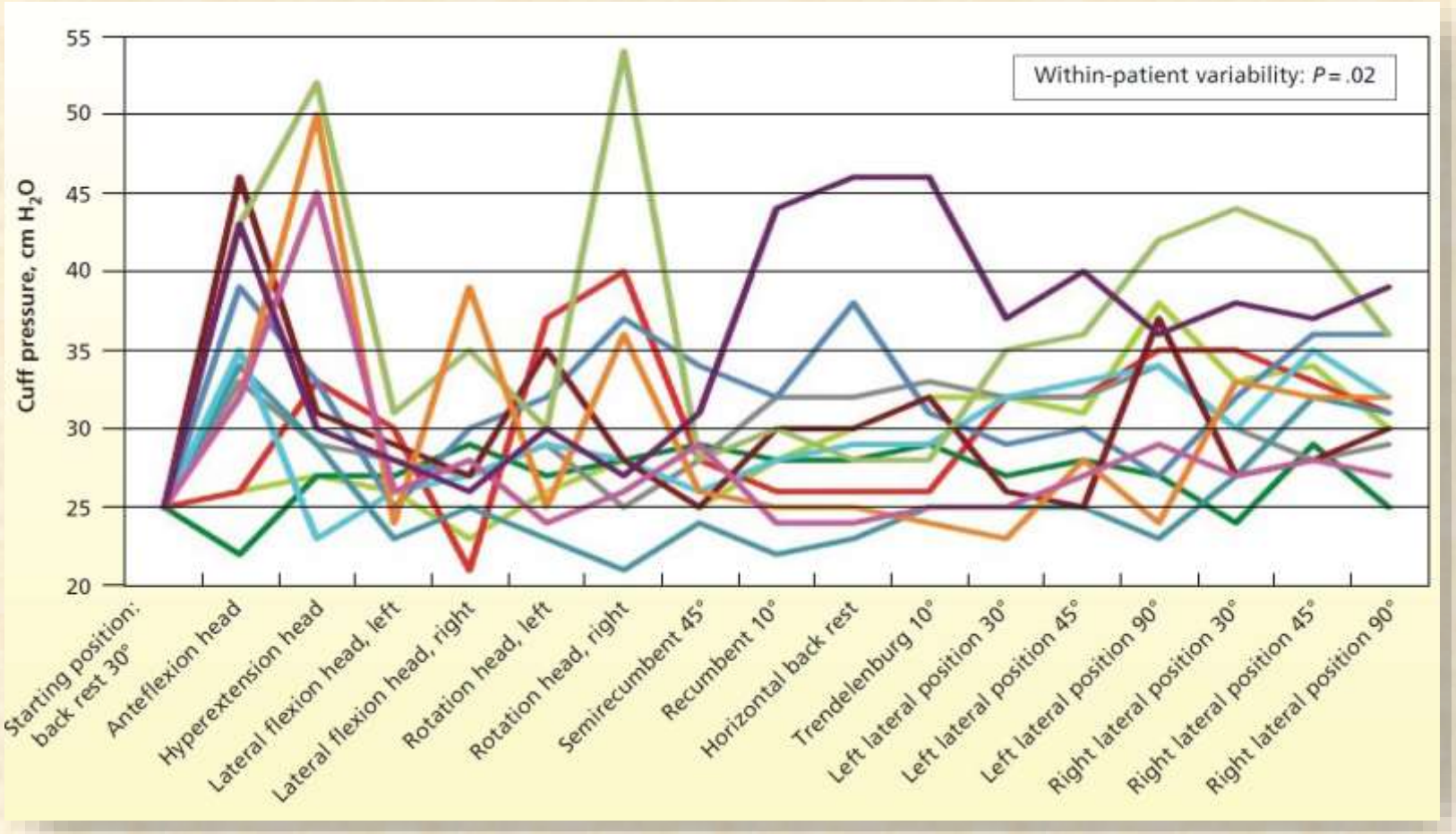
- 192 measurements made in total

Christelle Lizy, et al. Am J Crit Care 2014;23:e1-e8



Christelle Lizy, et al. Am J Crit Care 2014;23:e1-e8

Significant within-patient variability (cannot predict)



Christelle Lizy, et al. Am J Crit Care 2014;23:e1-e8

- 40.6% were greater than 30 cm H2O & none were less than 20 cm H2O
- Cuff pressure remained within the target interval in all 16 positions for only 1 patient
- Indicate that cuff pressure should be measured after each change in a patient's body position
- Supports use of continuous monitoring of cuff pressure with automatic adaptation to a preset pressure

Christelle Lizy, et al. Am J Crit Care 2014;23:e1-e8

Cuff pressure increases with altitude

- Air expands within the cuff due to lower atmospheric pressure
- n=10 intubated patient in aeromedical transport
- mean rise in cuff pressure was 23 cm H_2O when patients moved from sea level to a height of 3000 feet above sea level
- cuff pressure must be measured during transport to a different altitude and accordingly

Henning J, et al. Anaesthesia. 2004;59(3):252

Factors affecting cuff pressure

Increasing cuff pressure	Decreasing cuff pressure
Positive pressure ventilation	Sedation
Ventilation with nitrous oxide	Neuromuscular blockade
Altitude/ air travel	Hypothermia
Laryngeal spasm	Cardiopulmonary bypass
Laryngeal edema	With time
bronchoconstriction	

Bernhard WN, et al. Chest. 1985;87(6):720-725.
Tu HN, et al. Anesth Analg. 1999;89(1):187-190.
Bassi M, et al. Ann Emerg Med. 2010;56(2):89-93.e81.
Inada T, et al. Br J Anaesth. 1995;74(3):283-286.

Maintaining optimal cuff pressure in reducing long term complications

- Cuff pressures should be monitored routinely
- Typically assessed at every 8 hourly (atleast)
- Guidelines recommend a cuff pressure of **20 to 30 cm H2O**
- >30 cm H2O(20 mm Hg) damages the tracheal mucosa by compromising capillary perfusion
- >50 cm H2O: total obstruction of tracheal blood flow
- <20cm H2O : microaspiration→VAP

Lorente L, et al. Eur Respir J. 2007;30(6):1193-1207
Seegobin RD, et al. Br Med J (Clin Res Ed)1984;288(6422):965-968
Rello J, et al. Am J Respir Crit Care Med. 1996;154(1):111-115

Incidence of tracheal lesions

- Observational study to evaluate the tracheal mucosal lesions in intubated patients
- 83% patients who were intubated >48hrs had tracheal ischemic lesions, predominantly at cuff site and subglottis
- Duration of assist-control mechanical ventilation through a tracheal tube was the most important independent risk factor in causing these lesions
- Majority of these lesions(95%) healed 2 weeks after extubation

Lylia Touat, et al. Intensive Care Med (2013) 39:575–582

Stenosis

- retrospective review of all patients given a diagnosis of acquired laryngotracheal stenosis between 1997 and 2005 to identify its risk factors
- N=74 pts were identified compared with a control group without stenosis

TABLE 1. DEMOGRAPHICS OF LTS AND CONTROL GROUPS

	LTS	*Control*
Age (y)		
Mean ± SD	54.31 ± 17.35	57.02 ± 16.61
Range	17-84	21-93
Male	30	44
Female	44	62

LTS — laryngotracheal stenosis.

TABLE 2. COMORBID CONDITIONS IN LTS AND CONTROL GROUPS

	LTS	*Control*	*p*
Hypertension	34	52	.7620
Diabetes mellitus	17	25	1.000
Asthma	4	11	.2828
Chronic obstructive pulmonary disease	22	26	.4945
Gastroesophageal reflux disease	13	10	.1179
Sarcoid	1	3	.6446
Cicatricial pemphigoid	1	0	.4111
Wegener's granulomatosis	1	0	.4111
Relapsing polychondritis	1	0	.4111
Tracheomalacia	3	2	.4031
Obstructive sleep apnea	9	2	.008*
Airway trauma	10	5	.0529
Smoking	36	38	.1510
Alcohol use	21	20	.0928

Koshkareva Y, et al. Ann Otol Rhinol Laryngol. 2007 Mar;116(3):206-10

- Identified risk factors included
  - **Previous tracheostomy** were **10.99 times** more likely to develop LTS than control patients (95% CI 4.68 to 25.80)
  - **Irradiaton for carcinomas of the oropharynx and larynx** were **5.95 times** more likely to develop LTS than control patients (95% CI, 1.87 to 18.91)
  - **Previously intubated for more than 48 hours** were **3.91 times** more likely to develop LTS than control patients (95% CI, 1.91 to 8.02)
  - patients who were **intubated for any nonairway surgery** were found to be **2.07 times** more likely to develop LTS (95% CI, 1.09 to 3.93)

- The duration of intubation, the size of the endotracheal tube, trauma caused during intubation, the need for reintubation, and the presence of infection during intubation are all important contributing factors in other studies

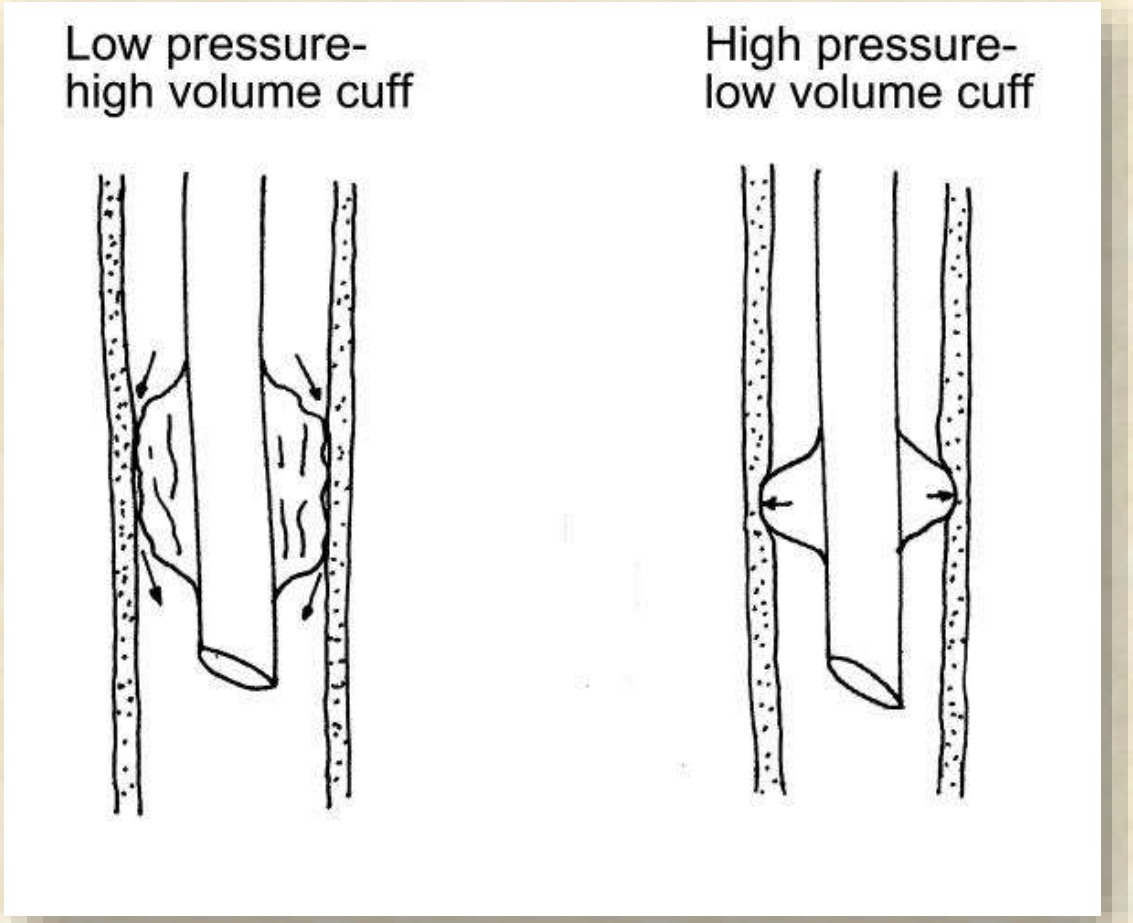
Goldenberg D, et al. Cummings otolaryngology– head and neck surgery. 2005(4):2103-28
Koshkareva Y, et al. Ann Otol Rhinol Laryngol. 2007 Mar;116(3):206-10

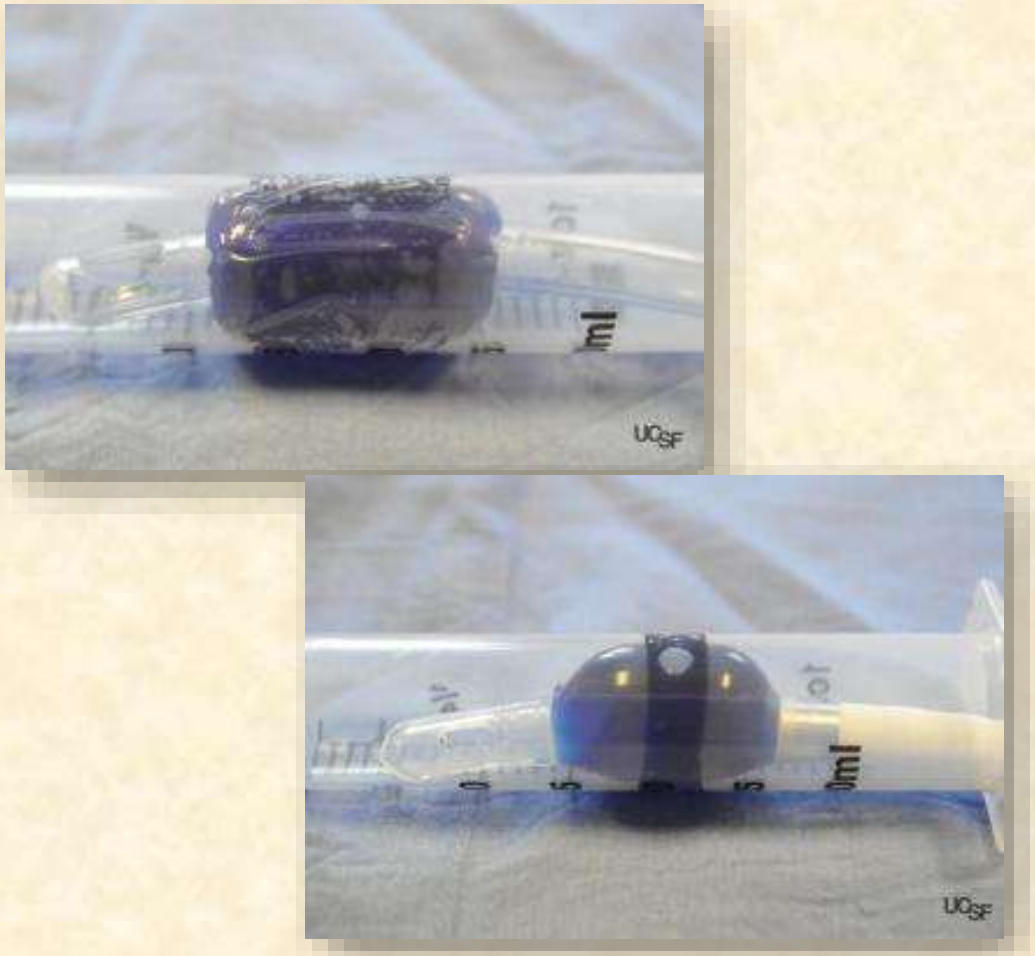

D-16


D-16

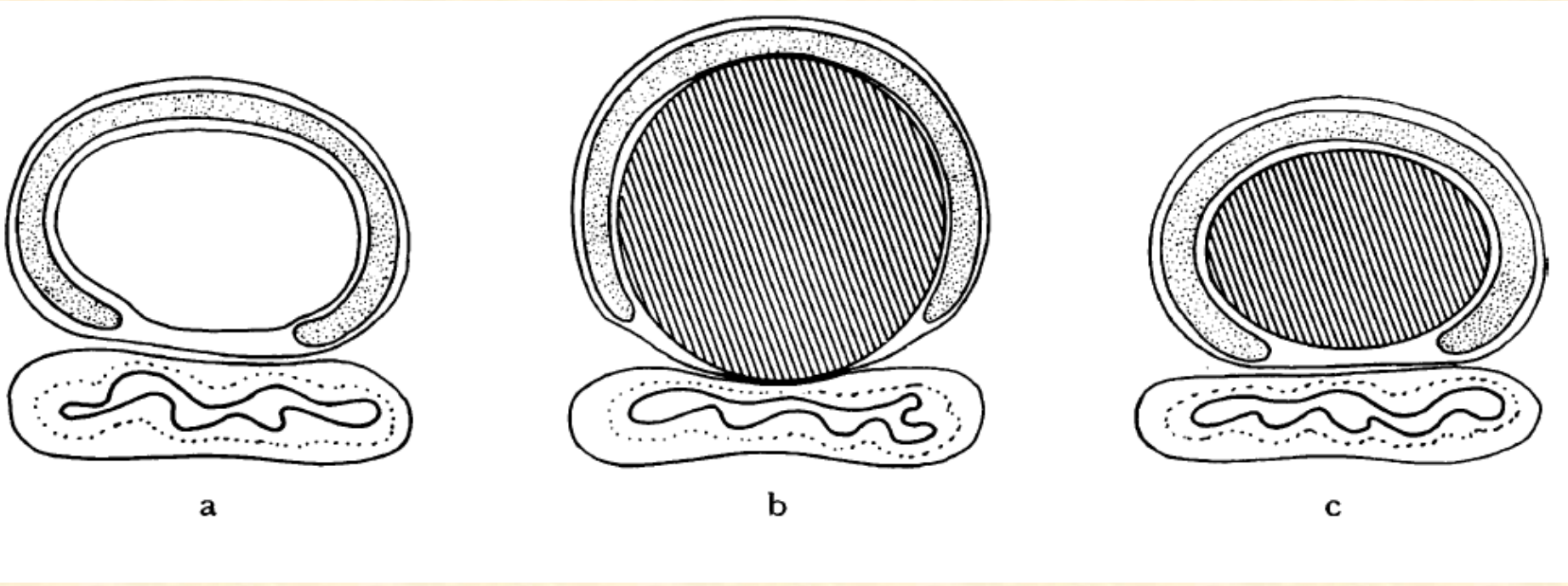
ETT designs to minimise cuff related injury

Types of ET tubes: LPHV vs HPLV





Colice GL, et al. Clin Chest Med 1991;12(3):433-448


a
b
c

Comparison

- Prospective observational study to compare the effects of two types of endotracheal tube, a high-pressure, low-volume type (Portex Blueline, PBL) and a low-pressure, high-volume type (Extracorporeal Lanz, EL)
- N=28 undergoing open heart surgery
- Fibreoptic bronchoscopy was then performed during extubation
- Tracheal mucosa was inspected from carina to the subglottic region and photographs were taken
- Bronchoscopist and independent observer scored the lesions based on oedema, inflammation, or ulceration (0-3 score/lesion)

D Honeybourne, et al. Thorax 1982;32:500-502

Table 2 *Scores of the bronchoscopist (A) and the independent observer scoring from photographs (B) for the damage caused by the two types of endotracheal tube*

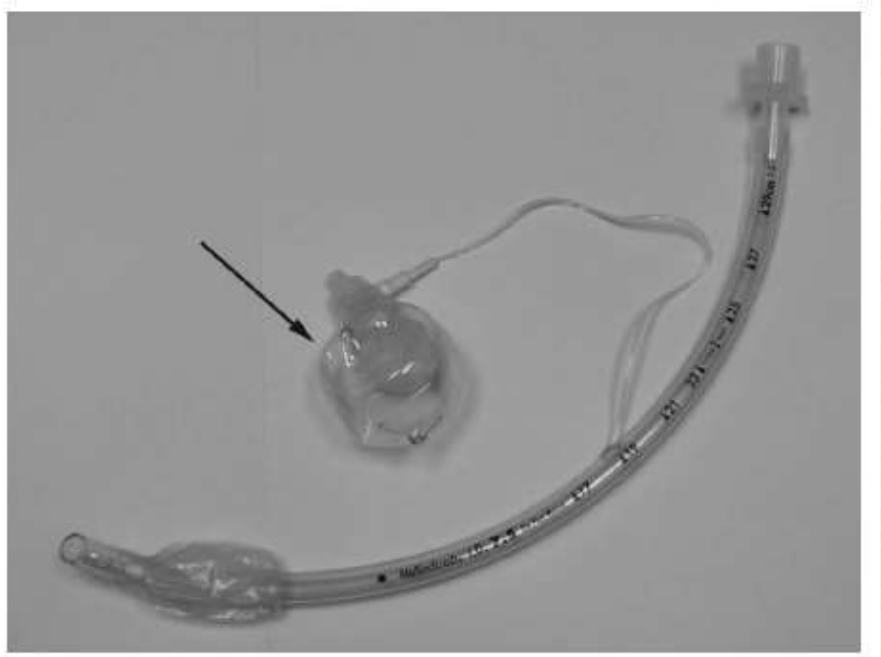
Tube	*Mean score A*	*Mean score B*
Portex Blue Line	5·9	5·8
Lanz	2·7	3·5
p value	< 0·01	< 0·05

- significantly less damage to the tracheal mucosa after intubation with the low pressure, high-volume type of endotracheal tube (EL) than the traditional high-pressure, low-volume type (PBL) and preferred in those requiring prolonged ventilation

D Honeybourne, et al. Thorax 1982;32:500-502

Lanz pressure regulating valve

- Replace the standard pilot balloon with a larger balloon containing an inner pressure-regulating valve that maintains intracuff pressure at 30 cm H2O
- Maintains a safe pressure and may be associated with reduced tracheal injury in few studies
- available in Germany but is not routinely used, possibly due to increased cost, the introduction of HVLP cuff designs



Leigh JM, et al. BMJ 1979;1(6172):1173-1174.
Seegobin RD, et al. BMJ 1984;288(6422):965-968

Low volume low pressure tubes

- Newer tubes with no folds on the cuff
- Proven to decrease the risks of pulmonary aspiration in rigid trachea models and pig benchtop models
- Dye leakage from subglottis into tracheobronchial tree reduced to 0% by using these LVLP cuffs

Young, et al. Crit Care Med 2006; 34:632–639)

- A Systematic review of OFTP included 28 studies and 54 subjects (15 pediatric)

Table 1. Pooled Analysis of Cases Included in the Systematic Review

Parameters	Values
Age, median (IQR) y	40.5 (14.8–60.5)
Female sex, *n* (%)	33 (61.1)
Indication of intubation, *n* (%)	
Post-surgery	21 (38.9)
Acute hypoxemic respiratory failure	19 (35.2)
Acute type II respiratory failure	4 (7.4)
Acute febrile illness	3 (5.6)
Community-acquired pneumonia	3 (5.6)
Trauma	4 (7.4)
Type of endotracheal tube, *n* (%)	
Magill rubber	3 (5.7)
Cuffed	20 (37.7)
High-volume low-pressure	12 (22.6)
Uncuffed	11 (20.8)
Double lumen	1 (1.9)
Tracheostomy	1 (1.9)
Traumatic intubation, *n* (%)	9 (16.7)
Size of endotracheal tube, median (IQR) mm	7.5 (6–9.3)
Cuff pressure, *n* (%)	
<25 cm H_2O	11 (20.8)
>25 cm H_2O	1 (1.9)
Duration of intubation, median (IQR) h	36 (14–96)
Time to onset of symptoms after extubation, median (IQR) h	24 (6–96)

IS Sehgal, et al. Respir Care 2016;61(9):1260 –1266

Prevention of PITS/OFTP by early tracheostomy

- No definite trials comparing prolonged intubation and tracheostomy in reducing long term complication rates
- Incidence of PITS is almost the same in both

- Location of the stenosis is different
- Repair and management of subglottic lesion is more difficult than tracheal lesions

PDT vs conventional tracheostomy

- Cochrane systematic review 10 studies, 643 participants
- Primary outcome was mortality
- Secondary outcomes were tracheal stenosis, tracheal malacia, delayed wound healing, cosmetic deformity, tracheocutaneous or oesophageal fistula
- Percutaneous tracheostomy significantly reduced the total number of late non-life threatening events (rate ratio 0.47, 95% CI 0.25 to 0.89, I^2 = 65%, P = 0.02
- Secondary outcomes were reduced by 53% (rate ratio 0.47, 95% CI 0.25 to 0.89, I^2 = 65%, P = 0.02)

https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD008045.pub2/epdf/standard

Tracheoesophageal fistula & tracheomalacia

Prevention (low level of evidence)

- Maintaining optimal ET cuff pressure
- Usage of high volume low pressure ET tubes
- Avoidance of prolonged duration of ventilation
- Avoiding excessive movement of ET tube
- Avoiding recurrent intubation

Dartevelle P, et al. Chest Surg Clin N Am. 1996;6(4):819-36

PITS: Our recent cases

Name	Age /Sex	CR No	Duration of ventilation	Type of tube	Place of ventilation
Krishan gupta	14/M	201806760221	12 days	HVLP tube	EMOPD B
Subhash	45Y/M	201805651453	5 days	Subglottic tube	RICU
Ishwar chand	48/M	201805700012	6 days	subglottic	RICU

Courtesy: Dr Deepa, Dr Vallianpan

OFTP: Our recent cases

Name	Age /sex	CR no	Duration of ventilation	Type of tube
Kiranjot	18/f	201805041205	3 days	HVLP tube
Prabha Oberoi	62/F	201806864272	16 days	HVLP tube
Santosh	50/F	201806263821	6 days	HVLP tube
Rani	31/F	201806310171	12 days	HVLP tube
Babli	25/F	201806321996	4 days	HVLP tube
Ishwar chand	48/M	201805700012	6 days	subglottic
Banto devi	56/F	201804682428	7 days	subglottic
malti	27/F	201804389321	2 days	HVLP tube

Courtesy: Dr Deepa, Dr Vallianpan

Take home message

General practice in ICUs for prevention of ET tube related complications

What we follow in RICU

- Frequent assessment of ET tube position done every 8 hourly (atleast)
- Ensuring adequate stabilization of tube by gauge tape or adhesive tape
- Avoiding frequent neck movement
- daily reassessment of the possibility of weaning from the ventilator and extubation to avoid unnecessary prolonged ventilation
- Ensuring proper functioning of ET cuffs before intubation
- Anticipation and preparedness for difficult airway

- Ensure adequate positioning of ETT before its removal for ET cuff leak
- Cuff pressures should be monitored routinely (q 8 h atleast) and maintained in the range of **20 to 30 cm H2O**
- high volume low pressure ET cuff preferred

What we can follow?

- Ultrasonography assessment for ET position (is better than auscultation)
- ?Subglottic ETT can be reintroduced
- ?prefer Manual monitoring of ET cuff pressure than automatic monitoring
- ?prefer PDT over tracheostomy

Thank you