General discussion and conclusions
After major surgery, artificial ventilation is often necessary to assist decreased respiratory effort due to anesthetic, sedative medication or surgical procedures. Artificial ventilation requires a tube, which is inserted through the glottis into the trachea. The mechanical ventilator pumps air through the tubes into the lungs. When a pre-set volume or pressure is reached, a valve opens the expiratory gate and air is released into the atmosphere. The presence of this tube in the trachea leads to impairment of mucus transport in the lungs and it becomes impossible for the patient to expectorate accumulated mucus. To relieve the patient of this accumulated mucus endotracheal suctioning is widely used. This procedure consists of disconnection from the mechanical ventilator, insertion of a suction catheter, and application of negative pressure resulting in extraction of mucus from the main bronchi and trachea. It is assumed that removal of mucus by endotracheal suctioning improves ventilation and prevents pulmonary infections. However, until now there is little evidence to support this assumption. On the other hand, many complications of endotracheal suctioning have been described: hypoxia, tissue trauma to the tracheal and bronchial mucosa, cardiac arrhythmias, cardiac arrest, respiratory arrest, pulmonary atelectasis, bronchoconstriction, infection, pulmonary hemorrhage, elevated intracranial pressure, hypertension and hypotension. Considering all these side effects, one wonders whether there is a different way of removing pulmonary secretions, equivalent in outcome to routinely performed endotracheal suctioning (RES) but with fewer side effects. In our main study, presented in chapter 2, we introduced an on-demand procedure of minimally invasive airway suctioning (MIAS) and compared this with RES. In RES, a normal 49 cm suction catheter was used. In case of MIAS, suctioning was performed with a custom-made short suction catheter of only 29 cm long, which could not reach the lower airways. Thus, only mucus from the tube was removed. RES and MIAS groups were prospectively compared for possible differences in duration of intubation, mortality, length of stay in the ICU, incidence of pulmonary infection, and incidence of suction-related adverse events. Suction-related adverse events were defined as any observed cardiac or respiratory symptom occurring within 10 minutes after suctioning. On two ICUs, 383 patients were included in this
Patients allocated to MIAS were permitted treatment with RES only if one of the following conditions was present after clinical observation by nurses and confirmation by medical staff: 1) an acute and persistent (> 1 minute) decrease in oxygen saturation below 90% for which no other cause than mucus retention could be found, 2) unilateral hypoventilation indicating unilateral bronchus obstruction, 3) persistent coughing causing a-synchronized breathing on the ventilator and evident distress.

The results were analyzed on an intention-to-treat analysis and later also by a per-protocol analysis. By either type of analysis MIAS is bio-equivalent to RES in terms of duration of intubation, ICU mortality and prevalence of pulmonary infections. Furthermore, the results show that MIAS induces less suction related adverse events than RES. Although the conclusion that MIAS is at least bio-equivalent to RES is statistically sound, the significant number of protocol violations deserves further consideration. The nursing team found it difficult to rigidly adhere to the RES protocol if no secretions were audible or visible. Routine deep suctioning apparently is counter-intuitive in these cases. Conversely, not applying deep suctioning if one is convinced that sputum is present in deeper airways, impedes gas exchange and should be removed by RES, appears to be difficult as well, considering the number of protocol violations in this category. With our study design it cannot be excluded that indeed RES is what is called for in these situations. To answer the question whether RES is superior to MIAS in conditions where severe obstruction of the airway by sputum is presumed, a different study design should have been employed. Protocol violations where RES was chosen to supplement MIAS treatment were predominantly seen in patients with long stays in the ICU and bad outcome. These patients also showed a higher incidence of pulmonary infection. Theoretically MIAS could be the treatment of choice in ICU patients that do relatively well, while RES cannot be avoided in the sicker patients. Again, further research is needed to confirm the appropriateness of RES in these cases. Subgroups of special relevance should be defined in advance.

After discharge from the ICU, patients often report an unpleasant recollection of endotracheal suctioning at the ICU. In chapter 3, we describe the results of a study in which we compared patients’ recollection of RES or MIAS.
General discussion and conclusions

Consecutive adult patients with an intubation period exceeding 24 hours were included. Within 3 days after ICU discharge, all patients were interviewed regarding recollection and discomfort of suctioning. We analyzed data from 208 patients (RES: n=113, and MIAS: n=95). We found that 21% of the MIAS patients had a recollection of airway suctioning compared to 40% of the RES patients. This may be due to the fact that the induced stress reaction is higher in case of RES as compared to MIAS. This was further studied in chapter 4, where we compared changes in stress reactions during RES and MIAS. In this study 16 intubated stable ICU patients participated, without noradrenalin or adrenalin infusion for the last 24 hours. RES and MIAS were applied in each patient in a crossover design. Arterial blood samples were collected prior to and after the suctioning procedure. Blood samples were analyzed for noradrenalin, adrenalin and cortisol levels. We found that the increase in stress hormones of noradrenalin and cortisol was higher in case of RES compared to MIAS. This indicates that RES is a more stressful intervention than MIAS. Generally speaking MIAS should be the treatment of choice to remove accumulated mucus in the artificial airway. However, RES treatment may be indicated in case of an acute and persistent (>1 minute) decrease in oxygen saturation below 90% for which no other cause than mucus retention could be found, in case of unilateral hypoventilation indicating unilateral bronchus obstruction, or in case of persistent coughing causing a-synchronized breathing on the ventilator and evident distress. It should be borne in mind that the nursing staff will tend to apply deep suctioning in very sick patients, not only in exceptional cases as defined above, but in all cases where the presence of deep-seated mucus is presumed.

In chapter 5, we have investigated the recollection of discomfort after discharge from an ICU. Within three days after discharge from the ICU, a structured, in-person interview was conducted with each individual patient. All patients were asked to complete a questionnaire consisting of 14 questions specifically concerning the environment of the ICU they had stayed in. Furthermore, they were asked whether they remembered any discomfort during their stay. If they did, they were asked to specify which sources of discomfort they could recall. We found that the prevalence of recollection of any type of discomfort in the ICU patients was 54%. These patients were asked to
identify the sources of discomfort. The results show that presence of an endotracheal tube (42%), hallucinations (32%) and medical activities (29%) were identified as sources of unpleasant recollection. Younger patients were at greater risk for remembering pain as source of discomfort. Patients with better factual recollection had greater recollection of discomfort. Adequate relief of pain is mandatory, but do these results suggest the use of higher levels of sedation? Deep sedation will obviously influence recollection, but there may be a less favourable side to this. Various authors have pointed out that, to prevent Post Traumatic Stress Syndrome, patients should be allowed a minimum of recollection of their stressful time in the ICU. Thus, total amnesia is perhaps not the answer to concerns about recollection of discomfort. Preventing discomfort by non-pharmacological means is probably to be preferred. The use of a shorter catheter for bronchial suctioning may be one of these alternatives.

Pulmonary function after mid- and upper-abdominal surgery decreases considerably. After extubation, patients are usually monitored by physical therapists in order to improve pulmonary function and to prevent pulmonary complications. Improving pulmonary function by breathing exercises is continued on the ward. Physical therapists use their clinical observation of breathing to determine whether a decrease of pulmonary function has occurred. In chapter 6, we investigated whether there is a relationship between clinical observation of breathing and decline in pulmonary function and the relationship between pulmonary function and pain. 89 Adult patients, scheduled for elective major mid- and upper-abdominal surgery, were included preoperatively. Breathing was assessed during maximum voluntary inspiratory effort while the patient was in a semi-recumbent position. Pulmonary function was evaluated with Forced Expiratory Volume in 1 second (FEV1), Forced Vital Capacity (FVC), and Peak Expiratory Flow Rate (PEFR), measured with the patient in the semi-recumbent position. The results of this study show that the relationship between clinical observation of breathing and pulmonary function is poor. Apparently, clinical judgment can only detect large changes in volumes by clinical observation of breathing. Pulmonary function tests can detect smaller decreases in FEV1, FVC, and PEFR.
Minimally invasive airway suctioning is equally effective as routine endotracheal suctioning but results in less suction related adverse events, less recollection of suctioning and less stress. Thus, although it cannot be employed in all situations, minimally invasive airway suctioning should be the “default setting” for mucus clearance in ICU-patients. Special suction catheters should be marketed that do not pass the distal tip of the endotracheal tube. Alternatively, standard catheters can be marked to avoid too distal routine suctioning.

An ICU can be considered a stressful environment, which may lead to unpleasant memories. It is as yet unclear how these can be avoided. Deeper sedation with standard drugs is not the answer as it increases the incidence of post-traumatic stress syndrome in the aftermath of a period on the ICU. A multidisciplinary team approach for patients discharged after a prolonged stay on the ICU may be appropriate.

After discharge of patients from the ICU to the ward current assessment of pulmonary function seems to be inadequate. Actual measurement of pulmonary function with a handheld spirometer should be implemented on the third day post surgery to evaluate possible pulmonary complications.
General discussion and conclusions