CHAPTER II

LITERATURE REVIEW

2.1 Theory

2.1.1 The Concept of Ventilator

2.1.1.1 Definition of Ventilator

A ventilator is the most widely used short-term life support technique globally, employed daily for various indications, ranging from scheduled surgical procedures to acute organ failure (Pham et al., 2017). A ventilator is a respiratory device that replaces the role of the lungs in the ventilation process. It supports ventilation by regulating volume, pressure, or a combination of both (Sundana,2018).

Ventilators play a crucial role in expanding the lungs during inspiration, regulating the duration from inspiration to expiration, preventing lung collapse during expiration, and managing the time interval between the expiratory and inspiratory phases. Advanced ventilators are equipped with a pressure gauge, a pressure-limiting device to protect the lungs from barotrauma, alarms for high and low pressure, and a spirometer for lung volume control (Oktavian, 2020).

2.1.1.2 Types of Ventilator

Based on how they support ventilation, mechanical ventilators are categorized into two main types :

1. Negative Pressure Tank Respiratory

Negative pressure ventilators generate negative external pressure in the chest area by reducing intrathoracic pressure during inspiration. This allows air to enter and fill the lungs. In spontaneous breathing, respiratory muscles create negative pressure in the pleural cavity, establishing a pressure difference between the atmosphere and the intrathoracic space, which triggers airflow into the lungs. In this type of ventilator, air is mechanically drawn to create a vacuum inside a tank, resulting in negative pressure. This negative pressure causes the chest cavity to expand, which lowers pressure within the lungs and increases incoming airflow. When the vacuum is stopped, the pressure inside the tank equalizes with ambient pressure, making exhalation passive (Zuliani et al., 2022).

The advantage of negative pressure ventilators is that they don't require endotracheal intubation. However, their drawbacks include a large device size, uncertainty in minute volume, and difficulty in maintenance. This equipment isn't suitable for patients with unstable conditions or those with frequently changing ventilation needs; it's typically used for patients with chronic diseases such as COPD, chest

wall deformities (kyphoscoliosis), and neuromuscular diseases (Zuliani et al., 2022).

2. Positive Pressure Ventilation

Positive pressure ventilators work by expanding the chest and lungs during the inspiratory phase, thanks to the positive pressure delivered by the ventilator above atmospheric pressure. At the end of the inspiratory phase, the pressure in the lungs returns to atmospheric pressure, allowing air to passively exit during the expiratory phase. During positive pressure ventilation, the lungs are periodically inflated by applying positive pressure to the upper airway via a tight mask (non-invasive mechanical ventilation) or through an endotracheal tube or tracheostomy (Hidayat et al., 2022).

The application of positive pressure mechanical ventilation alters respiratory physiology by transmitting positive pressure from the upper airway to the alveoli and chest cavity using an Endotracheal Tube (ETT), tracheostomy, or a mask (non-invasive ventilator), thereby creating positive pressure in the pleural cavity (Zuliani et al., 2022).

2.1.1.3 Indications for Ventilator Placement

Ventilator support becomes necessary when a patient's spontaneous ventilation is insufficient, leading to respiratory failure (Zuliani et al., 2022). According to Rehatta (2019), the indications for ventilator placement include several conditions:

1. Occurrence or imminent threat of respiratory and cardiac arrest.

2. Breathing difficulties (tachypnea) accompanied by increased ventilation demand and respiratory effort leading to respiratory muscle fatigue.
3. Severe hypercapnic respiratory failure unresponsive to Nasal Intermittent Positive Pressure Ventilation (NIPPV) therapy.
4. Severe refractory hypoxemia that cannot be overcome with Non-Invasive Ventilation (NIV).
5. Severe refractory metabolic acid-base disorders.
6. Inability to protect the airway.
7. Inability to clear secretions.
8. Requirement for hyperventilation or hypoventilation therapy.
9. Upper airway obstruction with poor airway patency.
10. Decreased respiratory drive characterized by bradypnea.
11. Coma with a Glasgow Coma Scale (GCS) score less than 8.
12. Experiencing severe trauma.

According to Pomtopidan (2003) in Oktavian (2020) a person needs ventilator assistance if they are in the following conditions:

1. Respiratory rate greater than 35 breaths per minute
2. Blood gas content with O2 mask PaO2 below 64 mmHg
3. Kandungan gas darah dengan O_2 masker PaO_2 dibawah 64 mm/g
4. PaCO2 exceeding 74 mmHg
5. Vital capacity below 15 mL/kg body weight

2.1.1.4 Ventilator Placement Procedure

Mechanical ventilator placement serves to take over the work of the respiratory muscles. Before connecting the ventilator machine, an endotracheal tube (ETT) must be inserted to deliver oxygen to the lungs. This process of inserting an endotracheal tube (ETT) is called intubation (Veterini, 2022).

Endotracheal intubation is a procedure of placing a tube into the trachea through the mouth or nose to manage the airway. This tube creates an open channel in the upper airway, allowing air to flow in and out of the lungs to provide ventilation. The patient will then be connected to a mechanical ventilator that supports continuous breathing through the endotracheal tube. To facilitate the intubation process, patients undergoing surgery are usually given general anesthesia and must undergo a sufficient fasting period (Sahiner, 2018).

According to Veterini (2022), for initial ventilator settings, the following steps can be followed in operating a mechanical ventilator. It's also important to check the manufacturer's instructions for each device before beginning installation:

a. Set the machine to deliver the required tidal volume (10 to 15 mL/kg)
b. Adjust the machine to provide the lowest oxygen concentration (FiO2) necessary to maintain PaO_2 within normal limits (80 to 100 mmHg). This setting may initially be high but will be gradually reduced based on arterial blood gas (ABG) analysis results

c. Record the peak inspiratory pressure
d. Select the mode (AC or SIMV) and size according to the healthcare provider's instructions. Set PEEP and PS if needed
e. Adjust sensitivity so the patient can trigger the ventilator with minimal effort (usually a negative inspiratory force of 2 mmHg)
f. Record the minute volume and perform an ABG to measure partial pressure of carbon dioxide (PaCO2), pH, and PaO_2 after 20 minutes of continuous mechanical ventilation
g. Adjust settings (FiO_2 and rate) based on ABG analysis results to achieve normal values
h. If a patient suddenly shows confusion or restlessness, or begins to resist the ventilator without clear reason, check for possible hypoxia and manually ventilate with 100% oxygen using a resuscitation bag

2.1.1.5 Principles of Ventilator Operation

At its most basic, a ventilator is a machine that helps move air into and out of the lungs. In a more sophisticated sense, a ventilator is a specialized device for moving a volume of air that can interact with the patient to adjust settings like the rate or pressure of the air being moved. The standard parameters for ventilators, according to the World Health Organization (2020), which serve as a reference for patient care, are:

1. Respiratory Rate (RR) Refers to how many breaths are delivered per minute. For ARDS (Acute Respiratory Distress Syndromme) it's

typically around 10 to 14 breaths per minute. The respiratory rate should range from 6 to 36 breaths per minute, with increments of 2

2. Tidal Volume (VT), this is the volume of air entering the lungs. It's usually around 400 to 600 mL. Tidal volume should range from 250 to 750 mL, with increments of 50
3. Inspiratory to Expiratory Rasio (I:E Ratio), this is the ratio of time spent exhaling compared to inhaling. It typically requires twice as long to exhale as to inhale
4. Peak end Expiratory Pressure (PEEP), this is the amount of pressure remaining in the lungs after exhalation. The lungs are like balloons filled with sticky glue and fluid. If a balloon completely deflates, all that material sticks to the walls, making it harder to inflate again. Therefore, the solution is never to let the balloon fully deflate. That's what PEEP does: it leaves some pressure in the lungs so they don't stick to themselves
5. Peak Pressure, this is the maximum pressure in the system. Its magnitude changes depending on whether PEEP is applied. Since the ventilator uses a closed system, if the patient coughs, there will be a rapid increase in pressure that can cause the lungs to rupture. This is not good. The solution is to use a pressure relief valve that opens when the system pressure becomes too high. The magnitude should be adjusted between 30 cm H_2O and 60 cm H_2O.

2.1.1.6 Ventilator Modes

According to Hidayat et al., (2022), based on cycling (the transition from inspiration to expiration), ventilator modes are classified as follows:

1. Pressure Limited / Pressure Cycled

   In pressure-cycled mode, the ventilator's pressure cycle switches to the expiratory phase when the air pressure reaches a preset level. Tidal volume (VT) and inspiratory duration vary, influenced by airway resistance, lung condition, and circuit compliance. These ventilators are more responsive to patient breaths, but a decrease in lung power or chest wall stiffness can lead to a reduction in tidal volume and minute volume.

2. Time Cycled

   In time-cycled mode, the ventilator switches to the expiratory phase after a specific period of time calculated from the start of inspiration. Tidal volume results from a combination of inspiratory time and flow rate. Time-cycled ventilators are typically used in operating rooms and for neonatal patients.

3. Volume Cycled

   The advantage of this ventilator mode is its ability to deliver a volume that can be adjusted to the patient's condition. Once the target volume is reached, the inspiratory phase ends. Many ventilators for adult patients use this mode, but they are equipped with a secondary limit on inspiratory pressure to protect the lungs from pressure-induced injury

(barotrauma). If the inspiratory pressure exceeds the set limit, the machine's cycle will proceed to the expiratory phase even if the desired volume has not been fully achieved.

4. *Flow Cycled*

   In this mode, the inspiratory phase will switch to expiration when the airflow drops to a certain level. Flow cycled ventilators are equipped with pressure and flow sensors that allow monitoring of inspiratory flow at a predetermined pressure; this transition occurs when the flow reaches the preset level.

2.1.1.7 Complications of Ventilator Placement

Various complications can arise from mechanical ventilation, some of which are life threatening:

1. Ventilator Associated Pneumonia (VAP)

   VAP is a type of pneumonia that occurs in patients in the intensive care unit (ICU) and is defined as a lung tissue infection developing after a patient has undergone invasive mechanical ventilation for at least 48 hours. VAP is one of the most common infections among patients requiring mechanical ventilation via endotracheal tube or tracheostomy (Papazian et al., 2022).

2. Ventilator Induced Lung Injury (VILI)

   VILI, or ventilator induced lung injury, includes atelectrauma, barotrauma, volutrauma, and biotrauma (Haribhai & Mahboobi, 2020).

3. Atelectrauma

Atelectrauma refers to lung injury arising from high pressures caused by atelectasis. Atelectasis itself is a result of prolonged sputum obstruction and long-term immobilization. To prevent this condition, several measures can be taken, including mobilization, chest physiotherapy, postural drainage, and sputum suctioning. If these methods are ineffective, sputum suctioning can be performed with the aid of bronchoscopy through an endotracheal tube or tracheostomy (Kumar dan Anjum, 2021).

4. Barotrauma

   Barotrauma is a type of injury that occurs when high pressure (exceeding 50 cmH2O) causes excessive distension of lung tissue (Zahrah, 2018).

5. Volutrauma

   Volutrauma results from alveolar edema and increased permeability caused by large tidal volumes, regardless of airway pressure (Zahrah, 2018).

6. Biotrauma

   Biotrauma refers to the biological response that emerges as a stress reaction to ventilator use. This is caused by the opening and closing of alveoli and excessive distension (Haribhai dan Mahboobi, 2021).

2.1.2 The Concept of Pain

2.1.2.1 Definition of Pain

According to the Internasional Association for the Study of Pain (IASP) pain is an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage. Pain is a personal experience influenced by various factors such as biological, psychological, and social aspects (Raja et al., 2020).

Pain is an uncomfortable sensory and emotional experience resulting from tissue damage. It can be interpreted as a complex and difficult-to-understand state (Ningtyas et al., 2023). A nursing definition of pain describes it as a painful bodily sensation based on the individual's statement, existing whenever the individual says it does (Nurhanifah & Sari, 2022).

2.1.2.2 Fisiologis Nyeri

Pain arises due to the presence of receptors and stimuli. The receptors that detect pain are called nociceptors, which are free nerve endings with little or no myelin sheath. They are distributed in the skin and mucosa, particularly in internal organs, joints, arterial walls, the liver, and the gallbladder. Pain can be felt when nociceptors activate afferent peripheral nerve fibers, namely A-delta fibers and C fibers. A-delta fibers have a myelin sheath, allowing them to transmit pain signals rapidly, providing a sharp sensation, precisely localizing the pain source, and detecting its intensity. Conversely, C fibers are unmyelinated and very small, making them less effective at transmitting localized and continuous

pain impulses. When stimuli from C fibers and A-delta fibers are received from the periphery, biochemical mediators such as potassium and prostaglandins are released in response to tissue damage. The process of pain signal transmission continues via afferent nerve fibers until it reaches the dorsal horn of the spinal cord. In the dorsal horn, neurotransmitters like Substance P are released, causing synaptic transmission from peripheral nerves to spinothalamic tract nerves, so the information can be immediately conveyed to the thalamus (Aydede, 2017).

2.1.2.3 Pain Classification

Based on its duration, pain is classified as follows:

1. Acute Pain

   Acute pain is a sensory or emotional feeling related to damage to physical tissues or bodily functions. It can appear suddenly or gradually and varies in intensity from mild to severe, but it lasts for less than 3 months (PPNI, 2016).

2. Chronic Pain

   Chronic pain is a sensory or emotional experience associated with actual or functional tissue damage. It can appear suddenly or gradually, with varying degrees of severity from mild to severe, and is continuous, lasting for more than three months (PPNI, 2016).

According to Pinzon (2016), based on the cause of pain, it is divided into:

1. Nociceptive Pain

Nociceptive pain is a type of pain that arises from mechanical stimulation of **nociceptors**. Nociceptors function as primary afferent nerves that receive and transmit pain signals. The free nerve endings of nociceptors are sensitive to various stimuli, including mechanical, chemical, thermal, and electrical, which can cause pain. These nociceptors are located in subcutaneous tissue, skeletal muscle, and joints.

2. Neuropathic Pain

   Neuropathic pain arises from lesions or dysfunction within the nervous system. This type of pain tends to be long-lasting and difficult to treat.

3. Inflammatory Pain

   Inflammatory pain occurs due to inflammatory processes and is sometimes included in the nociceptive pain category.

4. Mixed Pain

   Mixed pain refers to pain with an unclear etiology, being either nociceptive or neuropathic, or potentially caused by stimulation of both types. Common examples include lower back pain and sciatica resulting from a herniated nucleus pulposus (HNP).

According to Pinzon (2016), ased on its intensity, pain is classified as:

1. No Pain

   A state where an individual experiences no complaints about pain, or can also be interpreted as a pain free condition.

2. Mild Pain

A person feels pain with a low level of intensity. In this condition, the individual can still communicate well, continue daily activities, and experience no disruption in their activities.

3. Moderate Pain

   The pain experienced by a person is at a higher intensity. Typically, this pain begins to interfere with the individual's daily activities and elicits a more significant response to the pain.

4. Severe Pain

   Very intense pain is perceived as a burden by the patient, preventing them from carrying out normal activities. Additionally, this condition can cause psychological disturbances, where individuals might feel angry and lose control over themselves.

According to Pinzon (2016), based on the location where pain occurs, it is classified as:

1. Somatic Pain

   Somatic pain is pain that arises from stimulation of nociceptors, whether located on the surface or deep within the body. Superficial somatic pain is caused by stimulation of nociceptors found in the skin, subcutaneous tissue, or underlying mucosa. The symptoms that appear often include throbbing, burning, or stabbing sensations, and can be associated with conditions where normally non-painful stimuli (like allodynia) can cause pain, as well as hyperalgesia. This type of pain is generally

constant and has a clear location. Superficial pain often occurs as a reaction to cuts, scrapes, or minor burns.

Deep somatic pain is caused by damage to body wall structures, such as skeletal muscles. Unlike the dull pain associated with internal organs, somatic pain can be specifically localized on the body, although some types of pain can spread to surrounding areas. An example is postoperative pain that has a somatic component due to trauma and damage to skeletal muscles.

2. Visceral Pain

Visceral pain is pain that arises from damage to organs innervated by the sympathetic nervous system. Causes can include abnormal distension or contraction of smooth muscle walls, sudden traction on organ capsules (such as the liver), skeletal muscle ischemia, serosal or mucosal irritation, swelling or twisting of tissues connected to organs in the peritoneal space, and tissue necrosis. This pain is typically felt as a deep, dull, aching, pulling, squeezing, or pressing sensation.

2.1.2.4 Factors of Pain

Pain is complex and influenced by many factors. According to Smeltzer & Bare (2015), the following factors can affect pain:

1. Age

Age is an important element that influences the perception of pain, especially in children and the elderly. Children often have difficulty

understanding, expressing, and communicating the pain they experience.

2. Culture

   Cultural values and attitudes play a role in shaping an individual's pain experience and how they adapt to the condition. This includes an individual's reaction to pain.

3. Anxiety

   Anxiety tends to worsen the pain an individual experiences. In managing emotions, pain stimuli involve the limbic system, which functions to handle emotional responses to pain, either increasing pain or providing a pain-relieving effect

4. Previous Experience

   Every individual learns about pain from their past experiences. If someone frequently experiences the same type of pain and finds effective ways to cope with it, they will more easily understand and deal with that pain. Conversely, if someone has never felt pain before, their first experience can disrupt the pain management process.

5. Placebo Effect

   The placebo effect occurs when an individual believes that a certain therapy or action will yield specific results, thus experiencing benefits from that belief. This can enhance the effectiveness of independently taken treatments or actions.

2.1.2.5 Pain Response

After pain occurs, sufferers experience physiological and behavioral responses, which are referred to as pain reactions (Boer et al., 2019).

1. Physiological Response

   Physiological changes are more accurate indicators of pain than a patient's verbal explanations. In the case of unconscious patients, physiological reactions must replace verbal reports of discomfort (Boer et al., 2019).

Table 2. 1 Physiological Response to Pain

Response	Cause or Effect
Sympathetic Stimulus	
Bronchiolar dilation and respiratory rate increase	Increased oxygen intake
Increased heart rate	Increased blood pressure accompaniedshift of blood supply from the periphery and viscera to the skeletal muscles and brain
Peripheral vasoconstriction (pallor,increased blood pressure)	Generate additional energy
Increased blood glucose levels	Controlling body temperature during stress
Increased muscle tension	Preparing muscles to perform action
pupillary dilation	Allows better vision
Parasympathetic Stimulation	
Pale	Causes blood supply to shift from the periphery
Muscle tension	Due to fatigue
Heart rate andlow blood pressure	Due to vegal stimulation
Rapid and irregular breathing	Causes the body's defenses to fail due to prolonged pain stress
Nausea and vomiting	Restore digestive tract function
Weakness or fatigue	Due to the expenditure of physical energy

2. Behavioral Response

In a behavioral response, the client exhibits various reactions such as verbal statements, vocal behavior, facial expressions, body movements, physical contact with others, and changes in response to the environment (Aydede, 2020).

Table 2. 2 Behavioral Response to Pain

Behavioral Response to Pain	
Vocalization	1. Complain 2. Cry 3. Hard to breathe 4. Snoring
Facial exploration	1. Grimace 2. Grinding teeth 3. Frowning 4. Close your eyes or mouth tightly or open your eyes or mouth wide 5. Biting the lip
Body movements	1. Nervous 2. Immobilization 3. Muscle tension 4. Improved finger and hand movement 5. Stepping activity that occurs when running or walking 6. Rhythmic movements or rubbing movements 7. Movements to protect body parts
Social interaction	1. Avoiding conversation 2. Focus only on activitiesto relieve pain 3. Avoiding social contact 4. Decreased attention span

2.1.2.6 Pain Intensity Measurement

According to Pinzon (2016), the process of pain measurement follows the following hierarchical order:

1. Patient Report

Healthcare professionals should, as much as possible, elicit information from the patient's report. In patients with impaired verbal function, or in pediatric or dementia patients, efforts to obtain patient reports will be very limited, requiring further assessment.

2. Identify the Cause of Pain

   Carefully search for the presence or absence of potential pain causes. Pathological conditions or medical procedures (such as surgery, rehabilitation, wound care) can cause pain to arise. In a patient undergoing such procedures who cannot independently communicate the presence of pain, it is assumed that the pain exists. Procedure related pain should receive adequate therapy.

3. Observe Patient Behavior

   In cases where there is no patient report about the presence or absence of pain, behavioral observation can be a valid measurement tool. Behaviors indicating pain have been studied in large epidemiological studies. Other causes of behavioral disturbances besides pain (e.g., discomfort, constipation) must be excluded.

4. Family Report

   Family members or caregivers can provide information regarding the patient's pain complaints or behaviors indicating discomfort (for example, grimacing facial expressions). Information provided by the family needs to be confirmed through observation by competent healthcare professionals.

5. Analgesic Administration

Empirical administration of analgesics can be done when pathological lesions or procedures that may cause pain have been identified. The choice of analgesic type highly depends on the severity of the pain, the type of pathological lesion present, and the history of previous analgesic use. An increase in pain-related behavior after pre-procedural analgesic administration indicates the patient is experiencing pain.

According to (Ardi, 2024) pain intensity measurement is divided into two categories:

1. Pain Measurement for Communicative Patients

a. Visual Analog Scale (VAS)

The patient marks their pain using a 100-millimeter (mm) line. The measured distance in mm can be interpreted as follows: 0-4 mm for no pain, 5-44 mm for mild pain, 45-74 mm for moderate pain, and 75-100 mm for severe pain. The Visual Analog Scale has also been modified into a pain assessment tool with a 0-10 numerical scale, where 0 means no pain and 10 means very severe pain (Khera & Rangasamy, 2021).

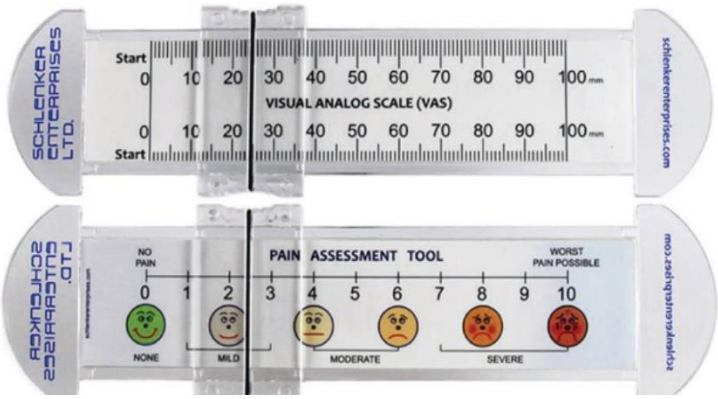

Figure 2.1 Visual Analog Scale

b. Numerical Rating Scale (NRS)

Patients who can communicate well can assess their pain by defining it with a number on a 0-10 scale, where 0 means no pain and 10 means the worst possible pain. Patients can also mark their pain on a pre-drawn Numerical Rating Scale (NRS) line (Khera & Rangasamy, 2021).

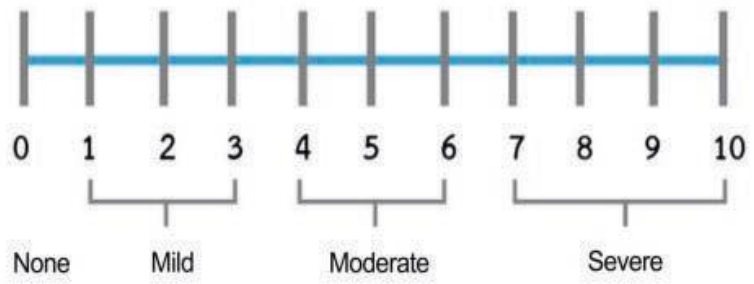

Figure 2.2 Numerical Rating Scale

c. Verbal Rating Scale (VRS)

The scale consists of 4 points: 1 indicates no pain, 2 indicates mild pain, 3 indicates moderate pain, and 4 indicates severe pain (Khera & Rangasamy, 2021).

2. Pain Assessment for Patients Unable to Communicate

a. Behavioural Pain Scale (BPS)

This measurement method relies on clinical observation of facial expressions, upper limb movements, and synchronisation with mechanical ventilation. BPS scores range from 3 to 12, with a score of >12 indicating a need for pain management (Rawal et al., 2019).

b. Critical Care Pain Observation Tool (CPOT)

The Critical Care Pain Observation Tool (CPOT) is another method

for pain assessment. It uses four components: facial expression, body movements, muscle tension, and compliance with mechanical ventilation for intubated patients, or vocalization for extubated patients. Each component is scored from 0-2, with a total score ranging from 0-8 (Rawal et al., 2019).

2.1.3 Pain Concepts in Ventilated Patients

2.1.3.1 Principles of Pain Assessment

The principles for assessing pain in critically ill patients are as follows (Khera & Rangasamy, 2021):

1. Understand and identify the causes of discomfort, acknowledging that while the majority of discomfort stems from pain, not all of it does
2. Routinely and accurately assess pain, sedation, and delirium using validated scales, and incorporate all other available supplementary information.
3. It's important not to rely solely on vital signs for pain assessment; instead, vital signs should serve as a basis for initiating a more comprehensive evaluation.

2.1.3.2 Factors Influencing Pain in Ventilated Patients

According to research by (Ayasrah, 2016), the following factors influence pain in patients on ventilator:

1. Age

   Physiological responses and pain perception tend to change with age. In the elderly, the pain threshold often decreases, but their verbal ability to

express pain also tends to decline. This reduced ability to communicate pain verbally is often compensated by non-verbal responses (Yamashita et al., 2017).

2. Gender

   Gender also affects an individual's pain tolerance, which is related to the prevailing paradigm that men are perceived as stronger than women. Differences in biological or hormonal states, as well as gender and social roles, create varying pain thresholds between men and women. Studies show that men generally have a higher pain tolerance threshold compared to women (Despiyadi, 2019).

3. Disease

   Pain, as an uncomfortable subjective experience, signals the presence of tissue damage or potential further tissue damage within the body. Degenerative diseases are among the most common causes of pain (Makinen et al., 2020). Comorbidities in ICU patients play a significant role in the pain experienced by these patients. A higher number of comorbidities increases the risk of ongoing inflammation (Jeitziner et al., 2015).

4. Post Operative

   The body's response to surgical trauma involves the activation of the peripheral and central nervous systems, as well as the release of inflammatory mediators like prostaglandins, bradykinin, and cytokines. This inflammatory process occurs locally at the surgical site but can also

be systemic, especially in critical patients, thereby intensifying the perceived pain sensation. In critical patients, this condition becomes even more complex because they often undergo various aggressive medical procedures such as major surgeries, placement of breathing aids, or other invasive therapies that increase the risk of acute and chronic pain (Makinen et al., 2020).

5. Level of Consciousness

   A decreased level of consciousness often occurs in ventilated patients, primarily due to the use of sedative and analgesic agents during intensive care. This condition significantly impacts a patient's ability to identify, perceive, and verbally express pain, making it difficult for them to convey subjective pain. The level of consciousness plays a crucial role in the pain experience of patients on mechanical ventilators. It has a close relationship with pain perception and reporting (Dewi et al., 2022).

6. Duration of Endotracheal Tube (ETT) Use

   Intubation during the ETT placement process triggers discomfort for ventilated patients. The presence of a foreign object for an extended period can cause laryngeal trauma and damage to the surrounding area due to cuff pressure. Pain resulting from ETT use is one of the most common complaints reported by patients. This pain typically lasts for the first 24-48 hours post-intubation and tends to persist (Ray et al., 2018).

2.1.3.3 Pain Responses in Patients on Mechanical Ventilators

Pain that isn't properly managed can lead to several physiological responses in patients on mechanical ventilators:

1. Hemodynamic Status

   Uncontrolled pain can cause hemodynamic instability, including a decrease in immune function and hyperglycemia (Dewi et al., 2022).

2. Oxygenation Status

   Patients experiencing pain tend to show a decrease in oxygen saturation. This occurs due to an increase in blood pressure and heart rate resulting from pain-induced stress, which can affect the body's ability to deliver oxygen to tissues (Dewi & Kariasa, 2022).

3. Heart Rate

   Pain in mechanically ventilated patients often leads to an increased heart rate. Pain triggers the activation of the sympathetic nervous system, causing tachycardia (rapid heart rate) as part of the body's stress response (Dewi & Kariasa, 2022).

4. Respirate Rate

   Pain is also associated with an increased respiratory rate. When patients experience pain, they tend to breathe faster as a response to meet the increased oxygen demand due to stress. In some cases, pain can lead to hyperventilation, where patients breathe faster and deeper, which can disrupt the body's gas balance and lower carbon dioxide levels (Dewi & Kariasa, 2022).

5. Body Temperature

The response to pain can also influence body temperature through physiological stress mechanisms, although this effect might be more complex and depend on many other clinical factors (Dewi & Kariasa, 2022). Prolonged pain can trigger inflammatory reactions that might contribute to changes in body temperature (Widiyastuti & Wulan, 2023).

2.1.3.4 CPOT (Critical Care Pain Observation Tool) as a Pain Assessment Instrument

Assessing pain levels in the Intensive Care Unit (ICU) is a challenge for healthcare professionals, especially for patients receiving sedatives and analgesics. Pain assessment becomes even more difficult when patients have neurological and psychiatric disorders like aphasia, dementia, critical illness-related delirium, or psychosis (Devlin et al., 2018). In its application as an assessment instrument for critically ill patients, the CPOT is easier to use and simpler to understand (Prawesti et al., 2016).

The Critical Care Pain Observation Tool (CPOT) instrument has four behavioral domains and is used to assess pain in adult patients with or without ventilators in surgical, medical, and trauma cases in the ICU. The advantage of the CPOT pain assessment instrument is that it is more specifically used for patients who cannot verbally communicate their pain and has been implemented in patients with head trauma, post-cardiac surgery, and medical conditions in the ICU. The advantage of the CPOT pain assessment instrument is that it's more specifically used for patients

who cannot verbally communicate their pain. It has been implemented in patients with head trauma, post-cardiac surgery, and medical conditions in the ICU (Wahyuningsih et al., 2017).

Table 2. 3 Critical Care Pain Observation Tool (CPOT)

Indicator	Description	Score	
Facial expressions	No muscle tension was observed	Relaxed, neutral	Facial expressions
	There are wrinkles on the face, drooping eyebrows, tense eyeball muscles and contraction of the elevator muscles.	Tense	1
	All of the above plus tightly closed eyelids	Grimace	2
Body movements	Not moving at all	Not moving	Body movements
	Move slowly, touch or rub the painful area, seek attention through movement	Protection	
	Pulling ETT, trying to sit up, moving limbs, not following orders, fighting against staff, trying to get out of the patient's bed	Restless/anxious	
Vocalization (non-intubated patient)	Speaking in a normal tone or no sound	Speaking in a normal tone or no sound	Vocalization (non-intubated patient)
	Moaning, sighing	Moaning, sighing	
	Crying, sobbing, crying	Crying, sobbing	
Ventilator compatibility (intubated patients)	The alarm does not sound, ventilation can be done easily	Can tolerate ventilator	Ventilator compatibility (intubated patients)
	Alarm stops spontaneously	Coughing, but can tolerate ventilator	1
	Out of sync, ventilation blocked	Fighting the ventilator	2
Muscle tension	No resistance to passive movement, relaxed	Relax	Muscle tension

Indicator	Description	Score	
	There is resistance to passive movement. Tense and stiff.	Tense and stiff	1
	There is very strong resistance to passive movement, unable to complete the movement, very tense/stiff	Very tense and stiff	2

Patients are given a score of 0 if their face is relaxed/neutral, characterized by no muscle tension. A score of 1 is given if the face is tense, indicated by furrowing of the brow, lowered eyebrows, and tense orbital muscles (muscles around the eyeballs). Patients receive a score of 2 if their face is grimacing, characterized by furrowing of the brow, lowered eyebrows, tense orbital muscles, and tightly closed eyelids. The assessment of facial expression using the Critical Care Pain Observation Tool (CPOT) is further illustrated in the following image (Jioe, 2018):

Figure 2.3 Facial Expression Assessment Using CPOT

According to (Lestari et al., 2024), the CPOT pain score classification is as follows:

1. No pain (0)
2. Mild pain (1-2)
3. Moderate pain (3-4)
4. Severe pain (5-6)
5. Very severe pain (7-8)

2.2 Theoretical Framework

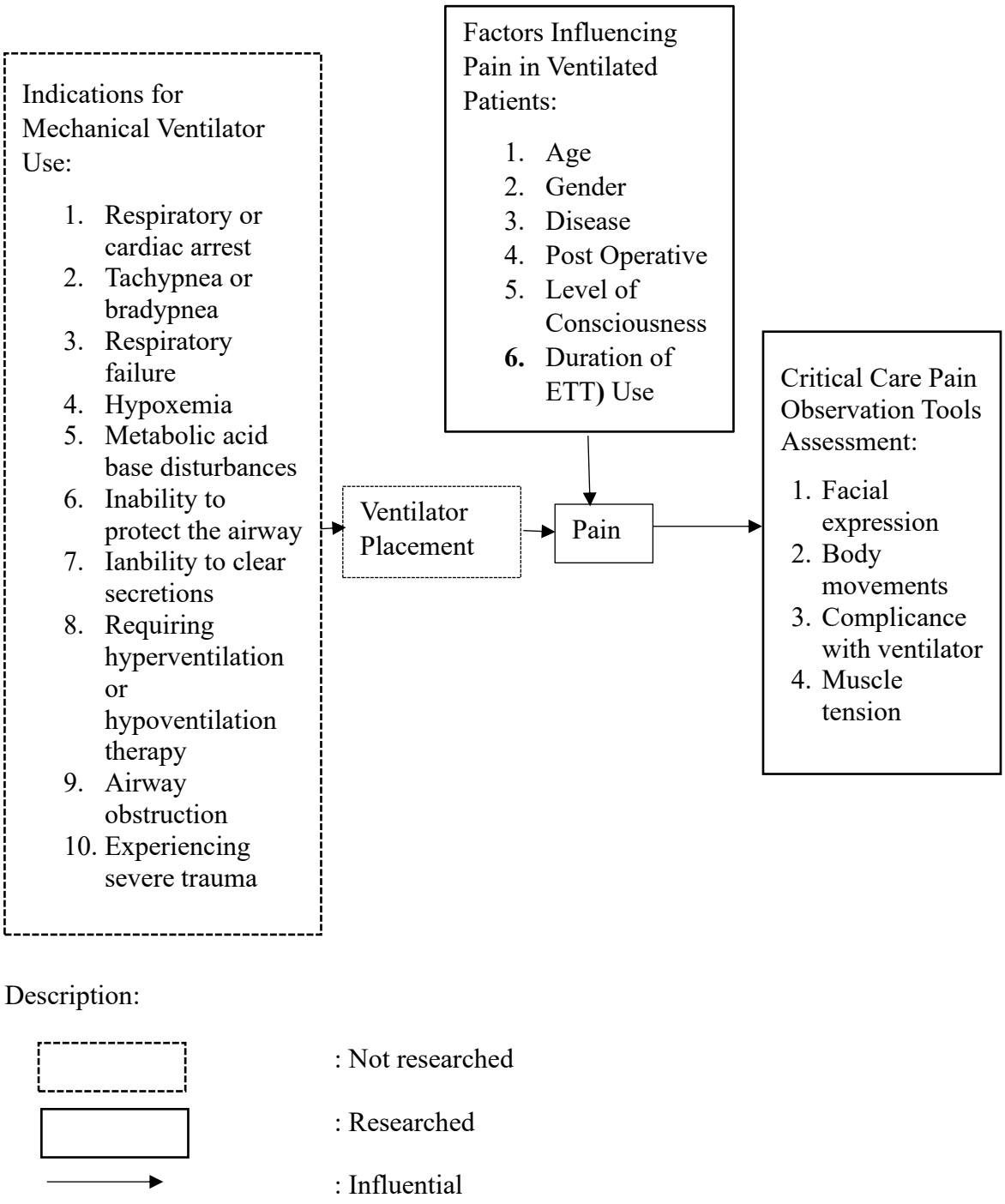

Figure 2.4 Conceptual Framework for Analyzing Factors Influencing Pain in Patients on Mechanical Ventilators Using the Critical Care Pain Observation Tool (CPOT)

2.3 Hypotesis

In this study, the following hypotheses can be proposed:

Hypotesis H_1 :

1. There is a relationship between age and pain in patients on ventilators at RSUD Ngudi Waluyo Wlingi.
2. There is a relationship between gender and pain in patients on ventilators at RSUD Ngudi Waluyo Wlingi.
3. There is a relationship between disease factors and pain in patients on ventilators at RSUD Ngudi Waluyo Wlingi.
4. There is a relationship between post-operative factors and pain in patients on ventilators at RSUD Ngudi Waluyo Wlingi.
5. There is a relationship between the level of consciousness and pain in patients on ventilators at RSUD Ngudi Waluyo Wlingi.
6. There is a relationship between the duration of endotracheal tube (ETT) use and pain in patients on ventilators at RSUD Ngudi Waluyo Wlingi.
7. There is a most dominant factor related to pain in patients on ventilators at RSUD Ngudi Waluyo Wlingi