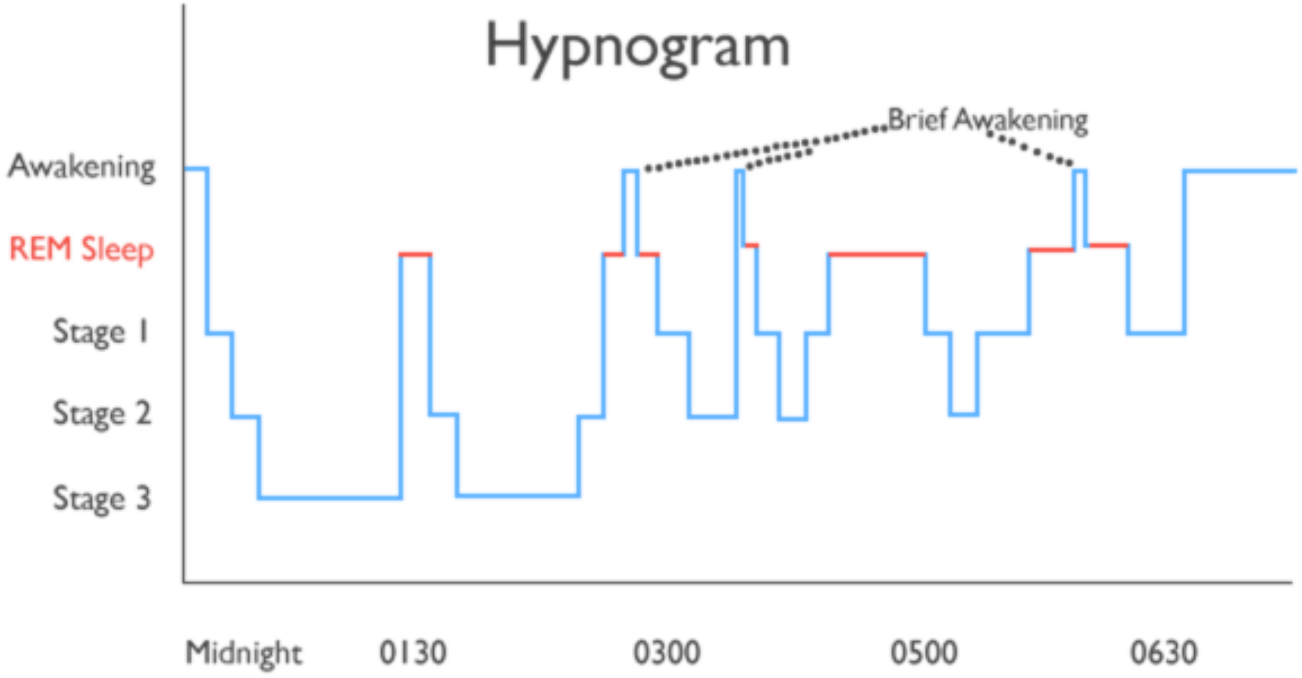
NORMAL SLEEP

Normal Sleep Patterns
Normal sleep is divided into two types, *Rapid Eye Movement (REM)* and *non-Rapid Eye Movement (NREM)* sleep. NREM sleep is further divided into 3 stages: N1, N2, and N3. Healthy sleep transitions occur between these phases during the night. The different stages can be identified by monitoring the electroencephalogram (EEG) of patients, as each has a characteristic pattern. Studying sleep using EEG recording is called *polysomnography*.
Hypnogram



REM SLEEP
REM sleep occupies 20-25% of each sleep cycle. It has two elements: *tonic* REM sleep is associated with skeletal muscle atonia (ie. total relaxation/paralysis); *phasic* REM sleep is associated with rapid eye movements, muscle twitches, and variation autonomic nervous system activity. The brain is very active during REM sleep, which is when dreaming occurs. Individuals are very difficult to arouse during REM sleep.
EEG appearances: low voltage, high amplitude mixed frequency beta waves and “saw tooth” theta waves

Non-REM sleep
N1 sleep
N1 sleep accounts of about 5% of total normal sleep, is the entry into sleep, and is the period of light sleep. It is sometimes called “drowsy sleep”. The muscles are active, and the eyes roll slowly.
EEG appearance: alpha waves and low voltage theta waves

N2 sleep

N2 sleep normally accounts for about 50% of sleep time. In this stage, it gradually becomes harder to awaken the sleeper and they lose all awareness of the environment.
EEG appearance: This stage is composed mainly of theta waves interrupted by abrupt activity called sleep spindles and K-complexes.

N3 sleep
N3 sleep is called *slow wave sleep* (SWS). It was previously divided into two phases (3 and 4) and accounts for about 25% of the total healthy sleep time. SWS is deep sleep and the individual is difficult to arouse and does not respond to external stimuli. SWS is thought to be important for restorative processes and also memory consolidation. Sleep walking, sleep talking, and night terrors occur during N3 sleep.
EEG appearance: This stage is characterised by high amplitude slow waves, namely delta waves.

PHYSIOLOGICAL CHANGES DURING NORMAL SLEEP

During normal sleep a wide range of physiological changes occur:

Temperature
Body temperature decreases during normal sleep, reaching the lowest point late during the night. REM sleep is associated with loss of normal temperature control mechanisms such as sweating and shivering.

Respiration
Normal responses to hypoxia and hypercapnia are reduced, especially during REM sleep. As sleep progresses from N1 to N3 sleep minute ventilation decreases and the $PaCO_2$ shows small increase, typically about 0.5 kPa. During REM sleep respiratory rate and minute volume may show wide variation.

Cardiovascular
During REM sleep, autonomic variation can result in bradycardia (parasympathetic activity) or tachycardia with hypertension (sympathetic activity). This has been associated with arrhythmia and myocardial ischaemia in patients with heart disease. During NREM sleep variation in cardiovascular status is uncommon.

Endocrine
Sleep and normal circadian rhythms are associated with characteristic hormonal variations. These include: melatonin secretion peaking around 2am; prolactin secretion peaking during later periods of sleep; cortisol secretion rising from the early morning; growth hormone peaking during SWS; and, thyroid stimulating hormone suppression during sleep.

SLEEP DURING CRITICAL ILLNESS

How is sleep altered during critical illness?

During severe or critical illness normal sleep is disrupted. Sleep deprivation and inability to sleep is one of the top complaints of ICU patients.

How normal sleep patterns are altered during critical illness:

The normal sleep cycles of REM and NREM sleep are maintained during critical illness.

- ○ True
- ◉ False

Correct. During severe illness patients have reduced or absent REM and N3 (SWS) sleep. These are thought to be important restorative sleep stages. Most patients experience only N1 and N2 sleep.

The total duration of sleep (total sleep time) is reduced during critical illness:

- ○ True
- ◉ False

Correct. In fact total sleep time is similar to healthy individuals. However, sleep is highly fragmented. Whereas most healthy individuals experience about 7 hours of continuous night-time sleep (cycling between REM and NREM sleep), critically ill patients experience multiple short periods (less than one hour) of N1/N2 sleep throughout the day and night. This is characterised by multiple arousals from sleep. Sleep quality and efficiency are therefore markedly reduced.

Sleep deprivation is associated with an increased risk of delirium

- ◉ True
- ○ False

Correct. The exact relationship between delirium and sleep is complex. Sleep deprivation seems to increase the risk of delirium, but conversely delirious patients are also at high risk of sleep disruption. Although unproven, it seems logical that interventions that reduce or shorten delirium may improve sleep.

The use of sedative drug infusions, such as propofol and midazolam, induce normal sleep.

- ○ True
- ◉ False

Correct. Although sedative infusions can produce an outward appearance of sleep, namely loss of consciousness and response to stimuli, they do not induce normal sleep. Benzodiazepines decrease REM and N3 (SWS) sleep; propofol decreases REM sleep occurrence and duration;

and, opiates also decrease REM sleep and profoundly suppress N3 (SWS) sleep. Drugs that increase the risk of delirium, especially benzodiazepines, may indirectly increase sleep disruption.

Mechanical ventilation contributes to sleep disruption

- (•) True
- ( ) False

Correct. Multiple factors result in frequent arousals from sleep during ICU care, such as noise and physical stimulation. However, it has been clearly shown that poor patient-ventilator synchronisation is a common source of arousal from sleep. This is most common with mandatory and volume-controlled modes such as SIMV. Sleep is likely to be least disturbed with pressure support modes, especially if adjusted to individual need. Modes that automatically adjust support to patient efforts, such as proportional assist ventilation, may reduce sleep disturbance.

Key point: Normal sleep patterns are severely disrupted in the critically ill. Restorative types of sleep, namely REM and "deep" N3 or SWS sleep, are lost or markedly reduced. Patients have frequent short periods of broken sleep throughout the day.

Although sedatives and analgesic drug infusions increase the outward appearance of sleep there is no evidence that they increase sleep quality. They may delay the restoration of normal sleep.

CONSEQUENCES OF SLEEP DEPRIVATION

Sleep deprivation has been associated with a wide range of physiological and psychological problems that are detrimental to health. Critically ill patients experience many of these problems during ICU stay and/or during their subsequent recovery.

The exact contribution of sleep deprivation to these issues is uncertain. Given many patients complain of sleep deprivation, and find it unpleasant and upsetting, it is logical to take steps to promote better sleep during and following ICU stay.

All of the following problems have been associated with sleep deprivation.

Physiological	**Psychological**
Inflammation	Delirium
Impaired immune function	Impaired memory
Increased energy expenditure	Depression
Hyperglycaemia	Cognitive impairment
Fatigue	Post-traumatic stress
Increased myocardial events (MI; arrhythmias)	Anxiety
Negative nitrogen balance (Loss of muscle; weight loss)	

IMPROVING SLEEP IN ICU

Improving sleep for ICU patients requires a comprehensive multifaceted approach that optimises the ICU environment for all patients, and addresses factors that disrupt sleep at individual patient level.

ICU level interventions	
Reduce noise generation	ICUs frequently exceed recommended noise thresholds during both day and night-time. Alarms, healthcare worker conversations, telephones, radios etc all contribute. Studies suggest that ICU patients attribute about 20% of awakenings to excessive noise.
Reduce noise exposure	Ear plugs and headphones have all been tried for sleep promotion. Some studies indicate these interventions can improve sleep based on polysomnography studies and patient questionnaires.
Light	Excessive intensity and duration of light can cause arousal, and can suppress melatonin secretion. Most studies indicate light is less sleep-disruptive to patients than noise. Reducing night-time lighting, and designing ICUs with more natural daylight may improve sleep quality.
Patient level interventions	
Patient Care activities	Studies show that frequent patient care activities disrupt sleep. These include therapeutic procedures (physiotherapy, venepuncture), nursing procedures (turning, bathing), and vital sign assessment (including clinical sedation scoring). Patients rate frequent patient care assessment as a major cause of sleep disturbance. Careful control of procedure timing, and periods of reduced frequency of assessment may improve sleep.
Mechanical ventilation	Studies have clearly shown that mechanical ventilation disrupts sleep and causes frequent arousals. Several mechanisms contribute: • discomfort from endotracheal tubes • poor synchronisation with the ventilator (coughing, straining, variable respiratory pattern) • Intermittent hypocapnia resulting in central apnoeas (intermittent hyperventilation from excessive support) Modes that either automatically adjust to patient efforts, or carefully individualised ventilator settings, can decrease arousals.

Pain	Many ICU patients have poorly managed pain. Optimising analgesia may improve sleep.
Delirium	Delirium is both a risk factor for sleep disturbance and a consequence of it. Minimising the risk of delirium and optimally managing it may improve sleep (see module 6).
Medication review	Many drugs used in ICU can disrupt normal sleep. Sedative drugs reduce conscious level, but disrupt normal sleep (decrease in restorative REM and N3 SWS sleep stages. In addition, many therapeutic drugs decrease REM and N3 SWS sleep. These include corticosteroids, catecholamines (norepinephrine, epinephrine), beta-blockers, and antidepressants. Review and discontinuation of unnecessary drugs may improve sleep.
Sleep-promoting drugs	Benzodiazepines and propofol infusion reduce consciousness but further disrupt normal sleep patterns. There is some evidence that dexmedetomidine may disrupt normal sleep less than other agents, but it is not licensed to promote sleep. Night-time administration of benzodiazepines and other agents with sedative properties, such as tricyclic antidepressants, are often used. These agents decrease REM and N3 (SWS), and may increase the risk of delirium. Their effectiveness is uncertain in ICU patients. The non-benzodiazepine GABA agonist drugs, such as zopiclone, may promote sleep with less disruption to normal sleep patterns than benzodiazepines. The use of sleep promoting sedative drugs should be carefully monitored and reviewed regularly.

SUMMARY

Sleep disturbance is very common in ICU patients and rated as one of the most distressing problems.

Although the total duration of sleep may be normal, it is highly fragmented occurring throughout the day in short periods. The quality of sleep is reduced, and there is marked reduction or absence of the restorative sleep stages, namely REM and stage N3 (SWS) "deep" sleep.

A wide range of environment and patient-level factors may contribute to sleep disruption. A multifaceted approach is needed to improve sleep in the ICU and during recovery.