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Sleep quality in hospitalized patients with advanced cancer: an observational study using self-reports of sleep and actigraphy

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Abstract

Purpose Although patients with advanced cancer report poor sleep quality, few studies have assessed sleep quality with a combination of subjective and objective measures. We aimed to examine sleep quality in hospitalized patients with advanced cancer by combining patient-reported outcome-measures (PROMs) and polysomnography (PSG) or actigraphy.

Methods A one-night prospective observational study of sleep in hospitalized patients with metastatic cancer using WHO step III opioids was conducted. Total sleep time, sleep onset latency, number of awakenings, and wake after sleep onset were assessed by PROMs and actigraphy. Sleep quality was assessed by the Pittsburgh Sleep Quality Index (PSQI) (range; 0–21), where higher scores indicate worse sleep quality.

Results Forty patients were monitored. Median age was 70, median oral morphine equivalent dose was 80 mg/24 h (10–1725), median Karnofsky Performance Score was 50 (20–90), and median time to death from inclusion was 38 days (4–319). Mean PSQI score was 6.5 (SD ± 3.4). PROMs and actigraphy of mean (SD) sleep onset latency were 46 (± 64) and 35 min (± 61), respectively, while mean time awake at night was 37 (± 35) and 40 min (± 21). PROMs and actigraphy differed on number of awakenings (mean 2 (± 1) vs. 24 (± 15), $p < 0.001$). Bland-Altman plots showed large individual differences between PROMs and actigraphy. PSG was not feasible.

Conclusions PROMs and actigraphy documented poor sleep quality, but a lack of agreement across methods. The study demonstrates a need to improve assessment of sleep quality and treatment of sleep disturbance in hospitalized patients with advanced cancer near end of life.

Keywords Sleep · Advanced cancer · Sleep diary · Actigraphy · Polysomnography

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Introduction

Patients with advanced cancer often report sleep disturbances [1, 2], with frequent sleep-related problems such as insomnia, restless legs, hypersomnolence, and sleep apnea [3]. Poor sleep decreases the tolerability of other symptoms and impairs quality of life (QoL) [4, 5].

Clinical sleep research should include composite sleep assessments with a combination of objective registrations such as polysomnography (PSG) and actigraphy as well as subjective (self-report) patient-reported outcome measures (PROMs) to give detailed information on sleep disturbances [5–7]. Moreover, monitoring of sleep should yield information about a number of relevant metrics, including sleep onset latency, wakefulness after sleep onset, total sleep time, sleep efficiency (percent of time asleep out of amount of time spent in bed), and sleep quality, reflecting a subjective global appraisal of each night's sleep [8].

Most studies of sleep in patients with advanced cancer use self-report. Self-reports reflect not only the quantitative sleep variables such as total sleep but also the patients' experience of sleep. Self-report is also more feasible than objective registrations. However, the use of objective measurements of sleep are increasing [4]. Good et al. recently applied PSG in patients with advanced cancer in a study that documented sleep and respiratory patterns [9]. Moreover, Bernatchez et al. applied actigraphy in advanced cancer outpatients and observed that both PROMs and actigraphy detected disturbed sleep [10]. In a large sample of 237 patients with metastatic colorectal cancer, Palesh et al. combined actigraphy and patient-reported subjective sleep and found sleep problems in 63% [11]. However, available studies that use subjective and objective measures of sleep usually include patients with early-stage cancer [12–15], with performance status of at least 60% [9, 11, 16–19], or outpatients [10, 20]. Thus, assessment of sleep by a combination of PROMs and objective measures, such as PSG or actigraphy, in hospitalized patients with advanced cancer approaching end of life, is scarcely investigated.

There are several reasons why we should examine sleep quality with both subjective and objective assessment in hospitalized patients with advanced cancer. These patients are often vulnerable, experience a high and fluctuating symptom burden [21], may be too weak to report sleep due to the disease, or are cognitively impaired [22]. Moreover, patients with advanced cancer use multiple drugs, including strong opioids [23]. Opioids might alter psychomotor function, mood, concentration, and other mental capabilities [24]. Thus, PROMs may not give an entirely representative assessment of sleep in patients with advanced cancer using strong opioids, due to the reliance on cognitive capacity to self-report sleep quality and symptoms. For these patients, objective sleep measures can supplement important information about sleep.

The aim of this study was to examine sleep quality by combining PROMs and objective measures (PSG or actigraphy) in hospitalized patients with advanced cancer.

Methods

Study design and patients

A one-night observational study of sleep quality in adult patients hospitalized for symptom control at a specialized inpatient unit was conducted at the Department of Palliative Medicine, St. Olav's hospital, Trondheim University Hospital, Norway. This unit has approximately 550 admissions a year with a median hospital stay of 7 days. Inclusion criteria for the present study were verified malignant metastatic disease, regularly scheduled WHO step III opioid treatment [25], and ability to comply with study procedures including at least one, preferably both, of the objective assessments PSG and actigraphy. A one-night assessment was chosen to reduce the burden on the patients in a setting with inpatients with an expected short survival. Patients were asked to wear the sleep equipment overnight (4 pm–9 am, a total of 17 h). Exclusion criteria were severe cognitive impairment as evaluated by the attending physician and inability to answer Norwegian questionnaires (Clinical Trials.gov identifier: NCT02585609).

Assessment of sleep quality with PROMs, polysomnography, and actigraphy

The primary purpose of this study was to explore sleep quality using objective (actigraphy and PSG) and subjective (PROMs) measures. The five sleep quality outcomes assessed by each measure were total sleep time (TST, i.e., the actual time slept in minutes); sleep onset latency (SOL, i.e., how many minutes it takes to fall asleep starting from the moment of intention to fall asleep); number of awakenings during the night (NWAK); wake after sleep onset (WASO, i.e., total amount of time awake during the night in minutes); and sleep efficiency (SE, i.e., percent of time in bed spent asleep) [26].

PROMs of sleep during the observation night were reported in a sleep diary [8, 26]. Patients were asked to record time to falling asleep, duration of sleep, and wake after sleep in a sleep diary. In the morning, total subjective sleep quality was assessed by one question on a numerical rating scale (NRS) 0–10, where 0 = best sleep and 10 = worst possible sleep, from the European Association for Palliative Care (EAPC) basic dataset [27], while sleepiness was assessed by the Karolinska Sleepiness Scale (KSS). The KSS is a 9-point Likert scale assessing the patient's perception of sleepiness. The nine answer categories range from 1 = very alert to 9 = very sleepy [28]. Patients also reported events that may have affected sleep/wake patterns during the observation night, e.g., symptoms or taking medications.

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Sleep quality during the previous month was measured by the Pittsburgh Sleep Quality Index (PSQI), a self-rating questionnaire for measuring subjective sleep quality [29]. The PSQI consists of 19 questions, which assess seven sleep components: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medications, and daytime dysfunction. Seven component scores on 0 to 3 scales are summarized to yield a global PSQI score between 0 and 21; higher scores indicate worse sleep quality. A global score > 5 is generally indicating poor sleep [29]. In addition, a score > 8 is suggested as more relevant to cancer patients [30].

Patients were asked to do a sleep polysomnography (PSG) test using the ambulatory equipment SOMNOscreen TM plus [31] to score sleep stages, awakenings, and respiratory parameters during one afternoon and a full night [17]. Supplementary Fig. 1 illustrates the clinical setup of PSG.

An actigraph is a small wristwatch-size device (Supplementary Fig. 2) which is used to assess sleep-wake cycles. It measures the degree and intensity of motion by means of a multidirectional piezoelectric accelerometer [32, 33]. In the present study, Actiwatch 2 (Philips Respironics, Inc., Murrysville, PA, USA) and Actiware software (version 6.0.7) were used to collect and analyze actigraphy data. Sleep estimates were automatically calculated by the Actiware software using the digital integration method [34]. The data were recorded with an epoch length (i.e., the period of time over which the actigraphy data is averaged) of 30 s and scored as wake or sleep by the use of medium sensitivity threshold, corresponding to 40 activity counts per epoch. A 10-min inactivity threshold for sleep onset was chosen as a default setting. All patients wore the actigraph around the wrist of their choice. The period of interest was sleep/wake during one night in the hospital. Based on differences in movement intensity, the software automatically defines rest intervals. In the present study, an initial visual examination of the actograms identified periods assessed as sleep despite apparent activity, and vice versa. Therefore, manually scored rest intervals were determined by a researcher (GJ) and a specialist in clinical neurophysiology (ME) following previously published criteria for rest interval onset (significant sustained decrease in activity, the patient-reported "lights off"), rest interval (significant sustained decrease in activity > 3 h), and rest interval termination (significantly sustained increase in activity, patient-reported "lights on") [32, 35].

Symptom burden and demographic variables

Cancer-related symptoms were measured by NRS in the EAPC basic dataset [27]. Overall QoL and pain during the last week were measured by the European Organisation for Research and Treatment of Cancer Core questionnaire for Quality of Life in palliative care patients (EORTC QLQ-C15-PAL) [36].

Sociodemographic and medical characteristics were obtained from the medical records. Morphine daily equivalent doses were calculated based on established definitions [25]. The treating physicians independently assessed performance status by the Karnofsky Performance Status Scale (KPS) [37]. KPS ranges from 0 (i.e., dead) to 100 (i.e., normal activity). Status of survival and date of death were obtained from the medical record 6 months after inclusion.

Statistical considerations

The sample size calculation was based on the expected precision of the observed mean of total sleep time, in minutes, measured by PSG. We estimated an expected standard deviation (SD) for total sleep time to be 60 min and assumed a normal distribution. We accepted an expected 95% confidence interval of 120 min (± 1 h). An estimation using these conditions, a significance level of 5%, and a power of 90% confirmed that 40 observations would ensure an acceptable (± 1 h) precision of the primary variable total sleep time.

Descriptive statistics were used for the sleep quality and demographic variables. Independent sample *t* tests were used to explore whether sleep quality in patients with a lower functional status (i.e., KPS ≤ 50) was different from sleep quality in patients with higher functional status (i.e., KPS > 50). Three approaches were used in the examination of agreement between PROMs of sleep quality and actigraphy. First, to evaluate possible relationships between PROMs and actigraphy, we calculated Spearman's rank correlation coefficient for the sleep parameters: total sleep time, sleep onset latency, number of awakenings, wake after sleep onset, and sleep efficiency. Second, after visual inspection, we concluded that the mean differences had normal distributions, and that the mean values of the abovementioned sleep parameters were compared using two-tailed paired *t* tests. Bland-Altman plots [38] were used to explore the agreement between actigraphy and PROMs. In this analysis, where A = actigraphy and B = PROMs, we calculated the difference between actigraphy and PROMs (A minus B), average [(A + B)/2], mean difference, and standard deviation of the differences. Mean difference between actigraphy and PROMs is the estimated bias, which is the systematic difference between the methods. The 95% limits of agreement were obtained (mean difference ± 1.96 SD) and data from the sleep parameters were examined visually by plotting differences between the actigraphy and PROMs (difference score = actigraphy minus PROMs) against their individual means in the Bland-Altman plots. To examine whether any of the observed discrepancies between the measurements could be accounted for by performance status, independent sample *t* tests were used. The KPS group ≤ 50 was compared with the KPS group > 50. Associations between actigraphy and PROMs on total sleep quality were examined by Spearman's rank correlations (r_s). There were no imputations

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for missing values on the PROMs. A significance level of $p < 0.05$ was used for all analyses. Data were analyzed by IBM SPSS Statistics version 20.0 for Windows (IBM Corporation, Armonk, USA).

Results

From January 2016, to March 2017, 41 of 128 screened inpatients were eligible (Fig. 1). Due to ongoing symptoms or poor condition, only two of the 41 included patients could use PSG. This method was therefore excluded from the study. However, all 41 patients entered a one-night assessment with actigraphy and PROMs of sleep. One patient died from cancer disease during the study night. For two patients, it was not possible to generate sleep parameters from the Actiware software. Supplementary Fig. 3 includes the actograms for these two patients.

Sample characteristics

All patients used step III opioids for cancer pain with a median oral daily morphine equivalent dose of 80 mg/24 h (range 10–1725). Median age was 70 years (range 41–91) and 40% were female. Median KPS was 50 (range 20–90). All had metastatic cancer and 33 of the patients (83%) died within 6 months. Median time to death from inclusion date was 38 days (range 4–319, interquartile range = 60.5, 25th percentile = 17.5; 75th percentile = 78). Other patient characteristics are given in Table 1.

The mean value on the overall QoL scale (0–100) was 51.8 (SD ± 25.4; 0–83.3) (Table 2). The mean pain intensity assessed in the morning on an NRS (0–10) was 2 (SD ± 2.8; range 0–10) (Table 2). Pain was the most commonly reported reason for disturbed sleep during the observation night (20%), followed by a need to use the bathroom (15%), disturbances from medical equipment, e.g., intravenous lines (10%) and racing thoughts (5%). Other symptom intensities are given in Table 2.

Patient-reported sleep

The mean patient-reported total sleep time was 442 min (SD ± 106), mean sleep onset latency was 46 min (SD ± 64), mean number of awakenings was 2 (SD ± 1), and mean total amount of time awake during the night was 37 min (SD ± 35). The mean percent of time in bed being asleep was 83% (SD ± 12) (Table 3). Frequency of missing PROM responses for the

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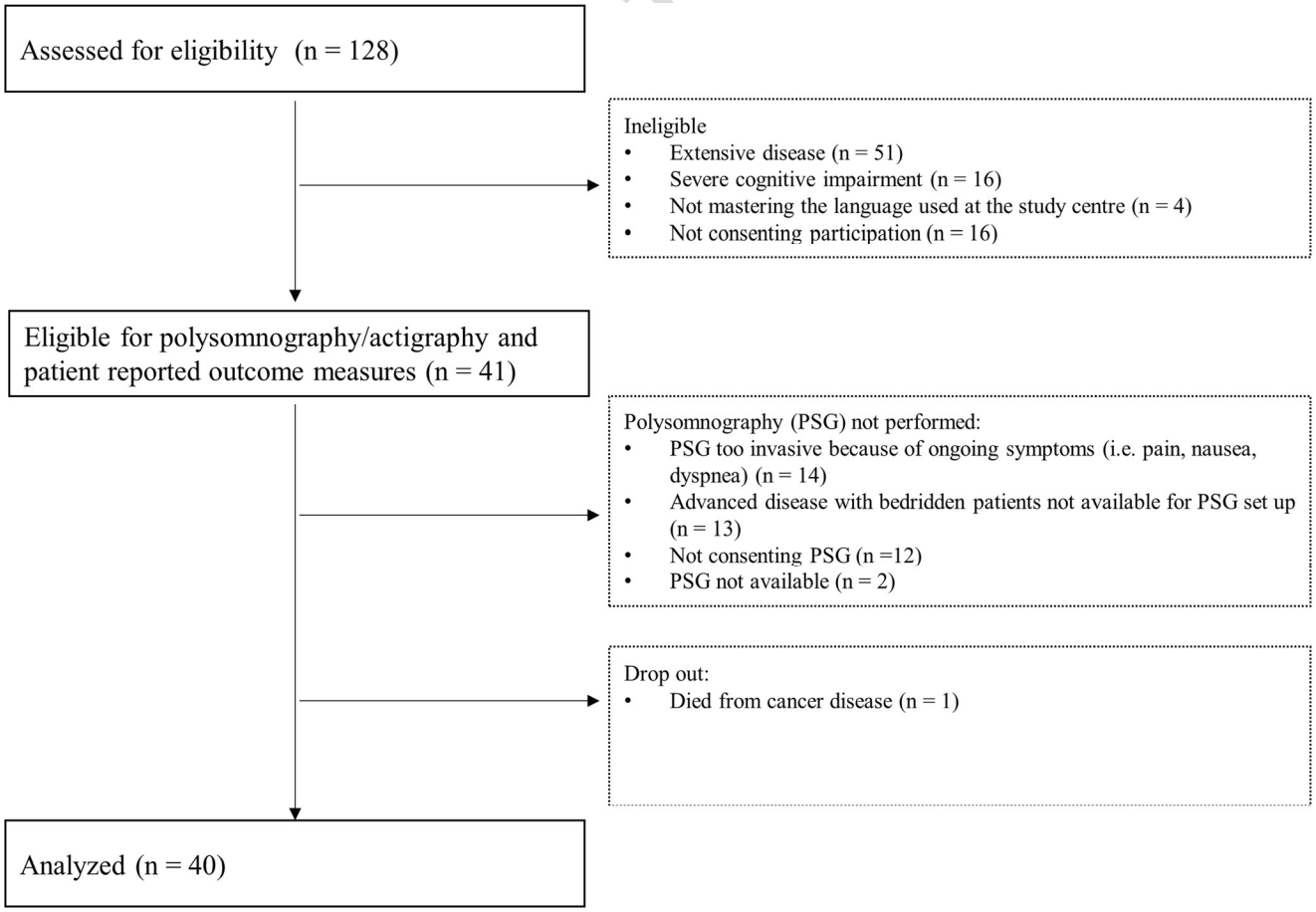

Fig. 1 Flowchart of the patient recruitment and completion of measurement

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Table 1 Demographic and clinical characteristics of the cohort at inclusion

Variable	Median (range)	*n* (%)
Age in years	70 (46–91)	
Karnofsky Performance Status Score[a]	50 (20–90)	
Oral daily morphine equivalent dose (mg)	80 (10–1750)	
Number of days on opioids	54 (7–710)	
Hemoglobin serum concentrations (g/dl)	11.6 (9–16)	
Number of drugs	9 (3–14)	
Time since cancer diagnosis (months)	30 (0–288)	
Gender		
Female		16 (40.0)
Male		24 (60.0)
Primary cancer diagnosis		
Gastro intestinal/liver/pancreas		22 (55.0)
Prostate		8 (20.0)
Pulmonary		2 (5.0)
Skin		2 (5.0)
Urological cancer		2 (5.0)
Breast		1 (2.5)
Female reproductive organs		1 (2.5)
Head and neck		1 (2.5)
Hematological		1 (2.5)
Metastases		40 (100)
Bone		18 (45.0)
Liver		19 (47.5)
Lung		15 (37.5)
CNS		2 (5.0)
Lymph nodes		13 (32.5)
Use of medication that may influence sleep:		
Steroids		25 (62.5)
Antidepressants		7 (17.5)
Sedatives/anxiolytics		8 (20.0)
Hypnotics		12 (30.0)

[a] Karnofsky Performance Status using a 0 (dead) to 100 (i.e., normal activity) scale [36]

Table 2 Descriptive statistics of global sleep quality and cancer-related symptoms

Variable	Mean	SD	Min	Max
PSQI global score[a]	6.5	3.4	2	13
Subjective sleep quality	1.1	1.0	0	3
Sleep latency	0.9	1.1	0	3
Sleep duration	0.3	0.6	0	3
Habitual sleep efficiency	1.2	0.4	0	3
Sleep disturbances	1.0	0.4	0	3
Use of sleep medication	1.0	1.3	0	3
Daytime dysfunction	0.9	0.9		
Karolinska Sleepiness Scale[b]				
Evening	6.4	1.8	3	9
Morning	4.8	2.1	1	8
Pain[c]				
Average pain, evening	2.2	2.5	0	10
Average pain, morning	2.0	2.8	0	10
Nausea[c]	0.9	2.3	0	10
Shortness of breath[c]	2.1	2.8	0	10
Depressionc	0.7	1.5	0	5
Anxietyc	0.7	1.6	0	6
Feeling of well-being[c]	3.4	2.8	0	10
Tiredness[c]	3.9	2.7	0	10
Drowsiness[c]	4.1	2.9	0	10
Overall QoL[d]	51.8	25.4	0	83.3
Pain last week[e]	66.1	29.4	16	100

[a] Sleep quality last month assessed by the Pittsburgh Sleep Quality Index (PSQI) [29]

[b] Karolinska Sleepiness Scale (1–9) [28]

[c] Assessed by the EAPC basic dataset, numerical rating scale 0–10 [27]

[d] QoL assessed by the European Organisation for Research and Treatment of Cancer Core Quality of Life Questionnaire (EORTC QLQ-C15-PAL) [36] for the last week (0–100), where a high score on overall QoL scale means a good quality of life

[e] Pain last week assessed on the EORTC QLQ C15-PAL symptom scale (0–100), where a high score on symptom scales denotes higher symptom burden

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selected sleep parameters were TST 27%, SOL 27%, NWAK 25%, WASO 50%, and SE 27%.

The mean PSQI global score was 6.5 (0–21) (SD ± 3.4). The PSQI revealed that 46% of the patients were categorized as poor sleepers defined by the PSQI global score > 5. Twenty-one percent of the patients had a PSQI global score > 8. Twelve patients were not able to complete the PSQI. The mean value of total sleep quality assessed in the morning on an NRS (0–10) was 3 (SD ± 2.5; range 0–8).

Sleep assessed by actigraphy

Actigraphy revealed that the mean total sleep time was 418 min (SD ± 138), mean sleep onset latency was 35 min (SD ± 61), mean number of awakenings was 24 (SD ± 15), and mean total amount of time awake during the night was 40 min (SD ± 21). The mean percent of time in bed spent asleep was 78% (SD ± 23) (Table 3).

There was no significant difference in sleep quality between patients with a lower functional status score (KPS of ≤ 50) and patients with a higher functional status score (KPS > 50) (Supplementary Table 1).

Agreement between PROMs and actigraphy

We observed differences between PROMs and actigraphy in some individuals. Further analyses showed moderate correlations (Spearman's correlations) between PROMs and

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t3.1 **Table 3** Sleep quality (mean ± SD) and comparison of sleep parameters estimated by actigraphy and patients reported outcome measures (PROMs)

Sleep parameters	Actigraphy (A) (mean ± SD)	PROMs (B) (mean ± SD)	Difference (A − B) (mean ± SD)	Spearman's rank correlation (rho)
TST (min)	418 ± 138	442 ± 106	− 23.8 (128.1)	0.61*
SOL (min)	35 ± 61	46 ± 64	− 11.4 (72.0)	0.26
NWAK	24 ± 15	2 ± 1	22 (14.4)	0.30
WASO (min)	40 ± 21	37 ± 35	3.6 (35.4)	0.21
SE (%)	78 ± 23	83 ± 12	− 5.3 (22.8)	0.48*

TST, total sleep time; *SOL*, sleep onset latency; *NWAK*, number of awakenings; *WASO*, wake after sleep onset; *SE*, sleep efficiency

*$p < 0.005$

actigraphy for total sleep time and sleep efficiency ($r_s = 0.61$ and 0.48) while sleep onset latency, number of awakenings, and wake after sleep onset all showed correlations below 0.40 (Table 3). Number of awakenings was statistically significantly higher based on actigraphy than PROMs with a mean difference of 22 (SD ± 14.8, $p < 0.005$). Compared with PROMs, the actigraphy measured lower total sleep time (23.8 min, SD ± 128.1), lower sleep onset latency (11.4 min, SD ± 70.7), lower sleep efficiency (5.3%, SD ± 22.8), and higher wake after sleep onset (3.6 min, SD ± 35.4). None of these differences were statistically significant, although an examination with the Bland-Altman plots demonstrated large variability in individual assessments (Supplementary Fig. 4). There were no differences in the discrepancy between actigraphy and PROMs in patients with KPS ≤ 50 ($N = 15$) compared with those with KPS > 50 ($N = 14$) (Supplementary Table 2).

Association between PROMs and actigraphy with total sleep quality and sleepiness

Finally, we also explored the associations between PROMs and actigraphy on total sleep quality. Total subjective sleep quality, assessed in the morning on an NRS (0–10), was associated with patient-reported sleep onset latency (Spearman's rank correlations (r_s) = 0.349), number of awakenings (r_s = 0.347), and wake after sleep onset ($r_s = 0.457$). Longer wake after sleep onset, as measured with actigraphy, was significantly associated with worsening of total subjective sleep quality ($r_s = 0.45$).

Discussion

The present study examined sleep quality in hospitalized patients with advanced cancer near end of life, who received strong opioids for cancer pain. Sleep quality was examined using a combination of PROMs and actigraphy. Both PROMs and actigraphy revealed poor sleep quality in one third of the patients.

To our knowledge, this is the first study examining sleep quality with the combination of PROMs and actigraphy in hospitalized patients with advanced cancer and short-expected survival time. Previous studies have usually included patients with early-stage cancer [12–15], higher performance status [9, 11, 16–19], or outpatients [10, 20]. Such studies may not be representative for hospitalized patients with advanced cancer at end of life. In these patients, sleep may be more affected than at earlier stages of the disease, and poor sleep might aggravate other symptoms or reduce quality of life. Thus, it is important to examine sleep quality in patients receiving palliative care, in order to improve future diagnostic and treatment of sleep disturbances, and as such make a novel contribution to the literature in this area.

Short sleep latency, few awakenings, and short wake after sleep onset are indicators of good sleep quality [39]. In this study, both PROMs and actigraphy revealed longer sleep onset latency compared with results from other studies in palliative care [11, 20]. However, the mean number of minutes it took to fall asleep as measured by actigraphy is shorter than in a study that examined the relationship between pain, sleep disturbance, and circadian rhythms in patients with cancer pain (35 vs. 41 min) [40]. Moreover, both PROMs and actigraphy showed that patients were awake more than 30 min on average during the night (37 and 40 min, respectively). These results agree with previous findings in outpatients with advanced cancer [10, 11, 20].

Using the suggested cutoff by Buysse et al. [29] for the PSQI (scores > 5), nearly half of the patients (46%) reported poor sleep quality on the PSQI questionnaire, which corresponds with high prevalence of self-reported poor sleep quality in advanced cancer patients observed in other studies [40–42]. Carpenter et al. suggested to use a PSQI score > 8 as the cutoff in cancer patients. This suggestion was based on the mean PSQI score in patients with sleep problems in their study [30]. A cutoff of > 8 have reduced the number of patients reporting poor sleep in our study. The argument for using a higher PSQI cutoff in cancer patients is to avoid influence of cancer-related symptoms on the sleep variable.

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We observed that almost one third of the patients could not report PROMs on sleep quality because of complex symptom burden and advanced disease. Therefore, to rely solely on PROMs in this group of patients will result in a lack of important information on sleep quality in many patients. In situations where patient perception about sleep is impossible, actigraphy provides useful feedback to health care providers about the overall sleep pattern [43].

Consistent with findings in the general population and in patients undergoing oncological treatment [11, 33, 44], we found discrepancies between PROMs and actigraphy. These differences between actigraphy and PROMs on sleep quality were larger in our study than in healthy individuals of similar age as in our sample, where the mean number and standard deviation of the difference between actigraphy and sleep diary for total sleep time was 13 and 62 respectively, compared with 23 and 128 in our study [45]. It has not been established to what extent the discrepancies between actigraphy and PROMs result from inaccurate measurements by the actigraphy or whether it is related to imprecise perceptions of sleep in the subjective patient reports or both [5]. In our study, the discrepancy could be affected by both erroneous interpretation of inactivity as sleep by the actigraphy and the patients' inability to report sleep. This issue could have been clarified using PSG. However, as illustrated in supplementary Fig. 1, PSG has a complicated setup that precluded installation of PSG in our cohort. Our lack of successful use of PSG illustrates the challenges in applying PSG for seriously ill patients with advanced cancer and should be carefully considered for future studies. PSG may be applicable in the palliative setting depending on the logistics of the study setting and the stage of disease, as shown by Good et al. who investigated sleep apnea in patients with advanced cancer [9]. However, in that study, time to death was not reported and patients may have survived longer than the median 38 days in our study.

Sleep quality is a complex construct to evaluate, and the discrepancy between subjective and objective measures of sleep may also be explained by PROMs and actigraphy measuring different dimensions of sleep quality [6]. It is previously reported that for older adults, perceived sleep quality is different from objective sleep quality [46]. Thus, in the assessment of sleep quality, patients' experience of sleep may be more important than some of the objective sleep parameters, such as total sleep time. Interestingly, patients' total sleep quality in our study was related to PROMs of sleep onset latency, number of awakenings, and wake after sleep onset, but not to total sleep time. This is similar to findings by Palesh et al. where subjective complaints of sleep disturbances were not associated with total sleep time duration in patients with metastatic colorectal cancer [11]. Also, for our participants, it seems that total subjective sleep quality was more influenced by perceived sleep disturbances than actual total sleep time. However, the low number of patients included precludes the analysis of other factors (i.e., anxiety, pain) that could influence sleep quality.

Strengths and limitations

An important strength of this study is the examination of sleep quality combining PROMs and actigraphy in hospitalized patients with advanced cancer near end of life. It is noteworthy that there are few, if any, comparable studies in similar populations. However, for reasons described above, PSG was not feasible in this cohort, which resulted in a lack of the gold standard of sleep evaluation [5]. Another limitation is that our study only had a duration of one night. However, this was decided to reduce the patient burden, and there is always a balance between the need to get optimal data and the consideration of the participating patients. Finally, the observation night was not standardized with respect to time since admission. Some patients were recruited upon admission, others shortly before discharge. Hence, one may speculate that improved symptom control during hospitalization might have been achieved after a few days and might have improved sleep quality. However, the sample size did not permit specific subgroup analyses nor was this not a specific study aim. Understanding sleep experiences of hospitalized patients with cancer at the end of life is important. Therefore, larger studies with a longitudinal design that combine objective and subjective sleep assessments are needed.

Conclusion

The present study showed that both PROMs and actigraphy documented poor sleep in hospitalized patients with advanced cancer. In individual patients, actigraphy and PROMs of sleep quality differed, reflecting a potential uncertainty related to these methods. Moreover, one third of the patients could not complete PROMs of sleep quality, and objective measures are needed to assess sleep. Our findings illustrate the importance of improving assessment of sleep quality and treatment of sleep disturbance in hospitalized patients with advanced cancer near end of life.

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Compliance with ethical standards

Conflict of interest Gunnhild Jakobsen, Morten Engstrøm, Morten Thronæs, Erik Torbjørn Løhre, Peter Fayers, Marianne Jensen Hjermstad, and Pål Klepstad have nothing to disclosure. Stein Kaasa is one of the shareholders in Eir Solution A/S and has research funding from Nutricia for other studies. He declares no income, dividend, or financial benefits from the work presented here.

Ethical standards The study was conducted in accordance with ethical principles in the Declaration of Helsinki and was consistent with ICH/Good Clinical Practice and applicable regulatory requirements. The Regional Committee for Medical and Health Research Ethics, Rec North, approved the study (approval number 2015/1631).

Informed consent Informed consent was obtained from all individual participants included in the study.

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