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Big data in healthcare system engineering and pain management

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Abstract

Healthcare is a system engineering which includes many aspects such as medical professionals, patients, technologies, insurance, policies, etc. Big Data analytics helps shape healthcare systems, achieve better outcomes, and lead innovation. Chronic and acute pain management expenditures are higher than ever before. Opioid use has become so prevalent that even adolescents are being prescribed narcotics for pain relief. However, opioid overdose has become a severe problem in the US and addiction tops the list for behavioral problems. First providers need access to medications such as Narcan which reverses the effects of opioids to reduce the effects and sequalae associated with opioid use. By using Big Data analytics, providers can manage the voluminous amounts of data associated with pain management such as genomics, proteomics, metabolomics, sensor data, smartphone data, social media data, etc. In this paper, we propose the application of Big Data tools to management of patients with all types of pain. By using this advanced data management system, providers take one more step towards personalized medicine.

Keywords: Big data, Big Data Analytics, Healthcare System Engineering, Pain Management, Opioid, MapReduce, Hadoop

1. Introduction

Treatment for both chronic and acute pain now dominates primary care, specialty care, and emergency departments nationwide. Providers are overwhelmed by the number of patients with chronic pain and clinics and emergency departments nationwide are not prepared to deal with the number of complaints related to opioid use. Self-medication with friends' and family members narcotics leaves many patients with fatal or near-fatal opioid intoxication. The use of narcotics on a regular basis for chronic pain results in a high number of drug addiction problems. All healthcare providers need to understand the problems associated with pain management and receive extensive training in working with these patients. Social media is an excellent resource for providers as patients who suffer from pain often turn to one of the numerous outlets such as Facebook, Twitter, Instagram, etc. as an outlet for expressing feelings related to pain management. Other important resources include smartphone apps, sensors, wristbands, etc. which can help document symptoms and side effects to help providers with treatment. It is important that society come to understand the complex intricacies associated with pain. Pain management treatment options can not only lead to overuse, misuse, and addiction; overdose, fatalities, and long-term disabilities can result from narcotic use. Another crucial factor to consider is provider attitudes about patients with pain. Patients who present in primary care are likely to receive more compassionate treatment than patients who present in the emergency department due to healthcare provider perceptions of seeking treatment for chronic pain in the emergency department of clinic. Long-term use of narcotics can also result in serious side-effects such as constipation, sleepiness, disability, depression, anxiety, etc. Public health has been seriously affected by the long-term use of opioids.

Modern data registries, created to take advantage of the use of EHR systems, are all wanting data to move directly from the medical record to the databank, without requiring human construct. The problem with this model is the heterogeneity of today's electronic data. A few elements, such as vital signs and medication doses, are relatively standard from one EHR system to another, but other essentials, such as outcomes and complications, are deficient in consistent definitions across practices and software vendors [1]. There are several types of questions that cannot be asked using single datasets that are supported by the availability of large shared datasets. In

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standard cognitive neuroscience studies, one generally uses a manipulation within a single task to identify the neural systems that are putatively involved in the manipulated mental process. This approach has resulted in the association of several brain regions with a varied range of mental processes; for example, the anterior cingulate cortex has been associated with mental processes as diverse as pain, speech, cognitive control and tongue movement. An alternative method, which has the potential to provide more selective structure-function associations, is to examine the underlying neural components that span across multiple task manipulations [2].

Undiagnosed or untreated depressive disorders are now a serious public health issue as well. Depressive disorders are sometimes accompanied by multiple medical problems, unexplained physical symptoms, chronic pain, all of which lead to higher and more frequent use of healthcare resources. Depression is prevalent among individuals of all ages, gender, and race. This results in extensive data and the potential to study it for multiple health related problems, such as detecting moods from tweets or understanding how people use such mediums for health improvement and support. Twitter use has been studied in multiple health-related situations, especially for public health campaigns. Public health surveillance can apply mined tweets and use a symptom-driven approach for early detection and analysis of epidemics, for example [3]. In research on substance use disorders (SUDs), data sources include imaging, phenotypic, molecular, exposure, clinical, health, behavioral, and many other types of data being generated by researchers, hospitals, mobile devices, etc. These data can reveal new treatments, discover the genetic and environmental causes of SUDs, and support the development of precision medicine in health care [4].

Data sharing is an essential element of applying the power of data science and information technology. Harnessing massive quantities of data generated by researchers from around the world has numerous methodological and economic advantages and provides incredible prospects for attaining new insight into addiction [4]. One of the most relevant discoveries about data is that as more data becomes accessible to computer algorithms, predictions can be made with greater precision. Research into the field of machine learning for natural language has found that statistical machine translation and statistical speech recognition have become much more precise as more and more data have become available [5].

Data is generated at increasingly high speed, and decision support must be made available near real time. Volume, Velocity, and Variety are the three Vs in the original definition of the key characteristics of big data. Other factors have also been well-thought-out, including Variability consistency of data over time), Veracity (trustworthiness of the data obtained), and Value [6]. Big data is most often connected to parallel programming paradigms such as MapReduce. Hadoop has been considered to store distributed databases as a basis for tools (e.g., Cascading, Pig, Hive) that allow the process of vast amounts of data [6]. Operational challenges related to data curation, development of advanced analysis tools (including machine learning and artificial intelligence techniques) and visualization strategies, and establishment of a culture of data sharing and direct access within the scientific community, need to be addressed. Big Data is now creating unprecedented novel opportunities to maximize the value of research results, giving researchers the ability to analyze massive amounts of data in new ways turning vast datasets of complex information into knowledge [4]. In this paper, we explore Big Data in healthcare systems engineering, Big Data in pain management, and the pathophysiology of pain and narcotic users. We aim to survey the literature for new technology as it applies to these concepts and hopefully provide solutions that can promote personalized medicine in the treatment of chronic pain.

2. Big Data in Healthcare System Engineering

Healthcare is a system engineering which includes many aspects such as medical professionals, patients, technologies, insurance, policies, etc. Healthcare systems also generate big data and advances in technology and data science have fostered the implementation of systems engineering in healthcare, including the following: a) consumer adoption of mobile apps and devices, b) advancement in machine learning and data analytics, c) interest in new forms of lower-cost treatment by health facilities, including the use of mobile services, d) reimbursement by Medicare and other health insurance providers for new digitally based health services, such as remote diagnostics, e) the flow of user-generated and biologically derived information that these devices track which will be fed through a vast Big-Data network composed of hospitals, pharmaceutical companies, consumer product goods and services companies, drugstores, and many other players both within and outside the increasingly porous connected-health system. Algorithmic classification systems could enable profiling and discrimination—based on ethnicity, age, gender, medical condition, and other information. The degree to which users of wearable devices will be able to make informed privacy decisions and therefore exercise meaningful control over their personal data will ultimately depend on the effectiveness of government and self-regulatory policies. Privacy, security, and consumer-protection policies for the connected-health market should be held to a much higher standard than those established for most other areas of the digital marketplace. The emergence of wearables is emblematic of the Big-Data era. Big-Data precision medicine initiatives also encourage public-private partnerships that generate breakthroughs for disease treatment and prevention. Health wearables, mobile apps, fitness trackers, smart watches, clothing, and similar consumer products are also outside of HIPAA's scope, except in very limited instances [7].

Clinical Decision Support Systems (CDSS) are widely applied in healthcare processes, such as triage, early detection of diseases, identification of changes in health symptoms, extraction of patient data from medical records, inpatient support, evaluation of treatment, and monitoring. Clinical datasets have a large or even endless data volume, which

exhausts significant resources for its computation and management. In addition to the large volume, the foundations of big datasets can be diverse and originate on different devices and platforms, which means that these data represent unstructured information and is not typically easy for traditional databases to analyze it. Accordingly, the main challenge of big data processing includes the extraction of useful and opportune information related to medical practices; from large volumes of a wide variety of data by enabling analysis, discovery, and interpretation. Machine learning (ML) methods may be applied into CDSS aiming to establish knowledge refinement and discovery with the purpose of giving reliable explanations and support to healthcare providers and patients. It is advantageous that these approaches provide not only superior performance but also the capability to handle missing and noisy data. Sometimes the ability to rationalize decisions, and the ability of the algorithm to reduce the number of tests necessary to obtain reliable diagnosis, are sometimes of vital importance [8].

Big data in health is concerned with meaningful datasets that are too big, too fast, and too complex for healthcare providers to process and interpret with existing tools. Speed, heterogeneity, and variety of data in health are challenges [6]. Veracity is key for big data as, for example, personal health records may contain typographical errors, abbreviations, and cryptic notes. Ambulatory measurements are sometimes taken within less reliable, uncontrolled environments compared to clinical data [6]. This information can be collected to help people manage simple chronic conditions, too. Early detection, supported by big data analytics which provide insights and pre-sights, is critical. Modern technology, including devices and wearables connected to the Internet, collects more and more data (big data), increasingly outside existing care providers. As such, the patient becomes the central node in the use of his or her own information, and therefore involved in the seamless delivery of the personalized services they need [9]. With the ability to deal with large volumes of both structured and unstructured data from various sources, big data analytical tools hold the promise to study outcomes, capture trends, and propose predictive models for data generated from electronic medical and health records. The use of natural language processing plays an essential role for systematic analysis and indexing of the underlying semantic contents [6].

Disparate data must be represented in a familiar format to enable comparison across multiple institutions and facilitate big data science. Nursing assessments epitomize a rich source of information however, a lack of agreement regarding essential concepts and standardized terminology prevent their use for big data science in their current state. To realize the benefits and opportunities of Big Data, a standardized and encoded set of data elements for nursing and patient assessment concepts is required. Big data creates an opportunity to explore the database or warehouse to explore live data and then determine predictive models allowing us to develop a patient-specific plan of care and improve patient outcomes. Physiologic evidence and specific pain measures are included in the nursing assessment and are documented in the EHR as pain is considered by healthcare professionals as the fifth vital sign. However, big data analytics depends on the use of standard terminology. Leveraging structured terminology such as Logical Observation Identifiers Names and Codes (LOINC) and SNOMED CT contributes to care collaboration, automated communication between nurses (as well as other health care providers), the determination of effective nursing interventions, and identification of evidence-based practice. Use of a multi-disciplinary standard terminology eliminates many of the barriers in achieving semantic interoperability in nursing. Encoded nursing assessments can be leveraged into clinical decision support applications or physician documentation. In addition, it promotes the continuity of care as a patient moves across primary, acute, or tertiary care. Sharable encoded patient data are the key to the evolution of nursing knowledge. In the future, we propose that this list of standardized assessment elements be incorporated into new systems, and that existing systems use these as a reference standard for interoperability. This will facilitate data exchange for individual care and support multi-site big data research [10].

Big data can be used to shape health policy to improve health, support evolving models of care delivery, achieve better outcomes, lead innovation, build strategic partnerships. Data analysis leads to the evidence and knowledge needed to inform health policy. More nurses are needed in leadership roles to influence practice, policy and data systems. Data, patient stories, and a consistent and active voice at all levels of nursing are needed to influence policy. Nursing needs to do more to advocate for policies that promote solutions to solve greater health care needs – for our special interest and for the public interest. We need to make sure nursing is at the table in big data analytics. It's critical to educate the broader population of nurses and nurse leaders about big data and its place in safe, high-quality patient care [11]. The implementation of essential basic big data courses in both undergraduate and graduate nursing programs is proposed so that future leaders are prepared to discuss necessary practice or policy changes to improve care or find solutions to the trickiest situations. Finding the right path to the implementation and widespread adoption of personalized medicine is an essential function for nurses at the undergraduate and graduate level.

A comprehensive, Big Data perception of phenotypic, genetic, and treatment variables promises to revolutionize medicine and medical treatment. There are also dangers to be evaded, such as the risks of misuse of personal data and new types of medical errors. We try to give a view into the future of Big Data in health, and to map out concrete steps that will help ensure that we can realize its full potential. Big Data allows for open data and the pooling of unrestricted government data and non-proprietary confidential data in an open data common will promote development of a Big Data health ecosystem. While use of Big Data holds out enormous promise for improving health systems, there are also dangers that must be avoided. Medical schools should also integrate Big Data analysis into

their curricula to enable the next generation of healthcare providers to integrate these advances into their medical careers. Such efforts, led by teams of computational social scientists and medical faculty, could also foster much-needed collaboration among the academic disciplines [12].

The mission of the National Institute on Drug Abuse (NIDA) is to advance science on the causes and consequences of drug use (including nicotine) and addiction and to apply that knowledge to improve individual and public health. The synergistic implementation and deployment of these technologies with Big Data mining will allow researchers to draw on unprecedented amounts of health information, transforming our understanding of how individual-level factors contribute to health and disease and ushering in a new era of personalized medicine [4]. The emergence of big data for health raises challenges in relation to privacy, security, data ownership, stewardship, and governance. It equally provides the opportunity to empower effective and precision medicine by performing patient stratification. This is a key task toward personalized healthcare [6]. Table 1 shows an example of challenges and progress of Big Data related technologies in dealing with neuroimaging data.

Table 1: Computational challenges and progress for big neuroimaging data [2]

Aspects	Description
Databases	Sharing large neuroimaging datasets requires powerful data management systems to organize and provide these data to researchers. A number of such systems have been developed, including XNAT, LONI IDA, LORIS and COINS.
High-performance computing (HPC)	Analyzing large MRI datasets requires access to high-performance computing systems. Given the parallel nature of nearly all the processing operations on the data, using parallel programming frameworks such as the Message Passing Interface is generally unnecessary, and substantial speedups can be achieved using standard grid engines without the need to modify existing software tools.
Cloud computing	As an alternative to transferring data to a local computing resource, it is increasingly possible to use the data stored on cloud storage systems. The primary disadvantage of cloud solutions is possible expensive costs.
Bandwidth	Providing very large datasets requires large amounts of bandwidth. The HCP has adopted a commercial solution (Aspera Connect) that accelerates file transfers; however, this tool is not sufficient for sharing the full HCP dataset. Peer-to-peer sharing systems such as BitTorrent has been used, however, such a solution is only viable for the data that is shared in a completely open manner.
Pipelines	A number of pipeline tools have been developed to process large neuroimaging datasets efficiently. Multiple pipelining solutions exist for neuroimaging analysis.

3. Pain Management

The Six Pillars of Pain Management [13]: (1) lifestyle modification such as exercise, sleep, nutrition; (2) optimizing medications; (3) psychological interventions; (4) physical therapies; (5) interventional therapies; and (6) spirituality and faith. Chronic pain is a persistent health problem, and the integral role that communication plays in chronic pain care is only beginning to be recognized. Patients and providers have described communication in chronic pain care as strenuous, hostile, and antagonistic. Interactions between patients and primary care providers (PCPs) in the context of chronic pain are frequently reported as tense and distrustful. Despite evidence suggesting the presence of serious communication difficulties in pain care, we have a paucity of data on the nature or causes of these problems or how to improve them [14]. Table 2. lists the mechanistic characterization of chronic pain. Figure 1 shows chronic overlapping pain conditions.

The subjective chronic pain experience is not linearly related to interoceptive and nociceptive signals from the periphery, but is constructed by the brain from peripheral and central (affective, attentional, memory) inputs. Chronic pain is a highly variable experience between affected patients and symptoms are quite often unreliable markers of the underlying disease process. Recent advances in neuroimaging techniques and analytic strategies have generated tremendous interest in applying readouts from multimodal neuroimaging as candidate biomarkers for various central nervous system (CNS) disorders, such as Alzheimer's disease, depression, schizophrenia and chronic pain [16]. Notably, the National Academies of Sciences, Engineering, and Medicine (NAS), in a published report, presents conclusive evidence that cannabis is effective in treating symptoms associated with chronic pain, the primary reason for which opioids are prescribed [17].

The most common diagnoses of chronic pain are low back pain, arthritis, and fibromyalgia. The Difficulties Scale, a patient self-reporting mechanism for pain management, permits patients to report their concerns or problems. Most patients described a ''medium'' level of difficulty for anxieties and complications related to opioid medications. The evolution of pain is uniformly represented beginning with an inciting injury or specific location on the body followed by the progression of pain over time. Patients tend to emphasize the role of opioid therapy for pain relief and their reliance on physicians for pain management. However, in exploring the cause of pain, patients tend to rely on objective or pathological findings as an explanation. By contrast, physician narratives utilize a more biopsychosocial model and physicians acknowledge the subjective nature of the pain experience and the challenges of evaluating and caring for the pain patient.

Table 2: Mechanistic characterization of chronic pain [15]

	Peripheral (Nociceptive)	Neuropathic	Centralized
Pathogenesis	Primarily due to inflammation or mechanical damage in peripheral tissue	Damage or entrapment of peripheral nerves	Primarily due to abnormal pain processing in the central nervous system although maintenance may require persistent PNS input
Favorable Treatment	NSAIDs, opioids, procedures (including surgery)	Pharmacological therapy targeting peripheral and central nervous systems	Neuroactive compounds affecting the central nervous system (SNRIs, tricyclic antidepressants, anticonvulsants)
Behavioral Factors	Minor	N/A	Prominent
Examples	Osteoarthritis Rheumatoid arthritis Cancer pain	Diabetic neuropathy Post-herpetic neuralgia	Chronic Overlapping Pain Conditions

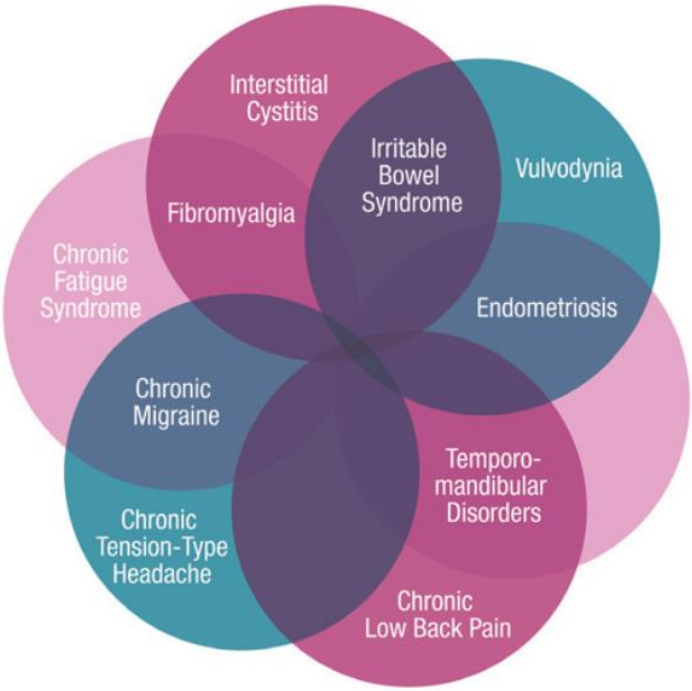

Figure 1: Venn diagram of chronic overlapping pain conditions [15]

Remarkably, most patients and physicians mention pain medications when describing the pain experience, as if medications were intrinsically linked to the understanding of pain itself. Many providers as well as patients, have negative attitudes toward drug seekers or drug addicts. For most patients, pain medications are taken to cope and for better function. But most doctors believe that pain medications are a superficial Band-Aid for a wound or a stepping stone to a drug addiction. Patient and physician narratives offer insight into the role of opioid pain medications as well as common

surrounding issues. Overall, physicians do not like prescribing long-term opioids for pain. Several physicians affirmed the utility of opioid pain medications, but rarely for chronic problems. The concerns they cited included the profound consequences of addiction, the lack of evidence in providing relief and improving function in the long term, and the desire to provide the best medical care for patients. There appears to be stigma attached to prescribing opioids, with several physicians stating they have few patients on long-term opioids as a provider and that would like to keep it that way. Chronic pain and the challenges of its treatment are pressing problems for patients and their physicians and for society at large, fueling initiatives, and demanding collaboration for all involved [18].

Low back pain, a primary chronic complaint treated with narcotics, is a common reason for activity limitation, sick leave, and disability. It is the fourth most common diagnosis seen in primary care. An expert group concluded that the most effective approach to manage non-specific low back pain is to discourage bed rest, to use over-the-counter pain killers in the acute stage if necessary (e.g., to be able to sleep), reassure the patient about the favorable prognosis, advise the patient to stay active, and advise strength and/or stretching exercise to prevent recurrence. Self-management in the form of physical activity and strengthening/stretching exercises constitute the core component in the management of non-specific low back pain; however, adherence to self-management programs is poor because it is difficult to make lifestyle modifications with little or no additional support [19].

The Institute of Medicine (IOM) report noted the increasing recognition and importance of chronic pain disorders that frequently cooccur and either solely or predominantly affect women. Even though the cause of certain conditions is unknown, some chronic and debilitating symptoms are known to increase long-term disability and premature death. Fibromyalgia is a chronic condition characterized by widespread, soft tissue pain, as well as accompanying comorbidities, such as disturbed sleep, fatigue and cognitive difficulties. Although low back pain is a symptom, according to the National Institute of Health (NIH) Task Force on Research Standards for Chronic Low Back Pain (cLBP), there is now increasing evidence that in its chronic form, it can progress like other chronic pain conditions, beyond a symptomatic state to a complex condition unto itself. Defined as “low back pain that occurs at least half of the days in the past six months,” symptoms include dull aching, sharp pain and/or tingling or burning sensations in the low back, defined as the lumbar region of the back between the posterior margin of the rib cage and the horizontal gluteal fold. Weakness in the legs or feet may also accompany these symptoms [15].

For chronic pain sufferers, narcotic use is almost always accompanied by a risk for addiction, sometimes a more severe addiction to illegal or street drugs. Misuse is high for individuals addicted to pain medication. Four in five new heroin users started out misusing prescription painkillers. People often share their unused pain relievers, unaware of the dangers of nonmedical opioid use. Most adolescents who misuse prescription pain relievers are given them for free by a friend or relative. Women are more likely to have chronic pain resulting in a prescription for pain relievers, be given higher doses, and use them for longer time periods than men. Women may also become dependent on prescription pain relievers more quickly than men [20]. We know even less about positive communication about chronic pain and opioid treatment and what factors are associated with communication that is positive and productive. Further complicating communication challenges is the uncertainty surrounding opioid treatment. This is a prominent fear because opioid prescriptions for chronic non-cancer pain have increased dramatically, with similar increases in opioid abuse and opioid-related deaths. In addition, despite the general agreement on the effectiveness of opioids for cancer pain and acute pain, the benefits of opioids for chronic pain are less clear, making productive communication about opioid treatment even more important. Communicating about opioids for chronic pain treatment remains a difficult problem for both patients and physicians, and research is still in its infancy. Most of the issues raised by patients were related to opioid treatment. Some patients complained in their interviews about previous PCPs. These complaints were related to dissatisfaction with the physician’s pain management. Patients sometimes complained that the perceived lack of caring resulted in not receiving requested opioids [14].

The Center for Disease Control (CDC) reported that there is not enough evidence to support the benefits of long-term opioid therapy for chronic pain. Providers should manage patients conservatively. Opioids are not to be used as first-line or routine therapy for chronic pain. Benzodiazepines and sedative hypnotics should be avoided when taking pain relievers. The rescue drug naloxone should be considered based on patient risk. Providers should set criteria for stopping or continuing opioid therapy when initiating therapy; as part of the discussion, document the criteria with a Controlled Substance Medication Management Agreement (MMA). Providers should also perform a urine drug screen and review records. Opioid therapy should only be initiated when all the following criteria are met: a) pain is moderate to severe, and adequate trials of other treatments and non-opioid analgesics have failed. b) the potential benefits outweigh the risks, and measurable treatment goals have been set. c) the patient is informed of the risks and benefits, and an MMA is signed. d) all medical records from referring providers are available, and drug tests are reviewed [21].

Opioid drugs can treat both acute and chronic pain. While these types of drugs, including fentanyl, hydrocodone, hydromorphone, meperidine, methadone, morphine, oxycodone, and oxymorphone, can have benefits for many patients with serious pain-related conditions, these drugs cause serious and substantial harm when used improperly. Even when used as directed, they contribute to overdose or lead to development of substance use disorder in some individuals. Opioid misuse places Americans at an elevated risk for heroin

use, overdose, and death. Use by injection places them at risk for exposure to blood borne diseases, including HIV and Hepatitis C. The Medicare population has among the highest and fastest-growing rates of diagnosed opioid use disorder. There is no systematic policy of screening for opioid use disorder and patients are unlikely to volunteer that they are misusing their medication or are using opioids like heroin because of discrimination and stigma. The mission of CMS's Opioid Misuse Strategy is to impact the national opioid misuse epidemic by combating non-medical use of prescription opioids, opioid use disorder, and overdose through the promotion of safe and appropriate opioid utilization, improved access to treatment for opioid use disorders, and evidence-based practices for acute and chronic pain management. Opioids are potent pain relievers that can cause potentially fatal central nervous system and respiratory depression, and their high potential for misuse has led to alarming trends of opioid misuse, use disorder, and overdose. Health and Human Services (HHS) has pronounced two key goals of its efforts to combat opioid misuse: (1) decreasing opioid overdoses and overall overdose mortality, and (2) decreasing the prevalence of opioid use disorder. The frequent and long-term use of these medications constitute a major part of the opioid epidemic. Primary care providers often lack training in the appropriate prescription of opioid medications. Prescription opioids often are diverted. Respiratory depression is a dangerous side effect of all opioids and is the cause of most of deaths due to opioid overdose. Naloxone is a life-saving overdose reversal drug that can be used to reverse the respiratory depression of an opioid overdose victim, but its availability during the critical moments of an overdose is limited. Naloxone would be in the hands of all first responders, including police officers, fire fighters, and other municipal staff. Health care providers would have substantial knowledge of the current best practices for pain management [22].

Tramadol appears to be used sometimes when clinicians are thinking of a long-term analgesic strategy. Opioids for 13 weeks have high probabilities of long term use and almost constant after that. Each additional day of opioid therapy increases the risk of chronic opioid use after three days of therapy. Prescribers should start with short-acting opioids and start a low increase slowly. Long-term use of opioids often begins with acute pain treatment. Re-evaluation is needed in about 1-4 weeks after starting opioids to treat chronic pain. [23]. There are often problems in inadequate treatment resources and training, abuse of prescription opioids, measuring outcomes, etc. Much treatment is done in primary care with difficulty triaging pain patients. The prescription opioid crisis and a need for better screening and risk stratification has resulted in the development of PainCAS™, a Web-based clinical tool for assessing and standardizing pain and opioid risk in chronic pain patients. The initial pain assessment includes 52 core questions requiring approximately 20-45 minutes of patient input. There is a follow-up pain assessment containing 23 core questions taking approximately 10-20 minutes by the patient. Screener and Opioid Assessment for Patients with Pain (SOAPP)® is another assessment with 24 questions initially, a 14-question follow-up, followed by five questions to complete the assessment. Current Opioid Misuse Measure (COMM)® is another pain assessment utilized by providers. Providers report pertinent positive information prioritized in at-a-glance graphic format. Graphics displays change over time indicating progress of the patient. Monitoring recommendations are based on opioid risk assessment and changes in pain and function show over time. The benefits lie in patient assessment results available in an at-a-glance format; timely access to assessment results; more meaningful dialogue with patients; and improvement in patient engagement [24].

To combat the rise in opioid use and opioid-related overdoses, the CDC published guidelines in March 2016 to improve opioid prescribing. Almost 60% of patients were initiated on short-acting hydrocodone. The highest probability of long-term opioid use was observed among patients initiated on a long-acting opioid followed by those initiated on Tramadol. Among patients initiated with Tramadol, over 64% of the patients who continued opioid use beyond one or three years were still on Tramadol. The probability of continued opioid use at one and three years for those starting on short acting hydrocodone or oxycodone, or Schedule III-IV opioids was similar. Few clinicians deliberately initiate chronic opioid therapy in non-cancer patients. Tramadol may be selected by clinicians when they are considering chronic opioid therapy as nearly one in eight individuals initiated on Tramadol remain on opioids one year later. Like other opioids, there is very little evidence on the long-term safety and efficacy of Tramadol beyond 12 weeks [25]. Opioid side effects, with prevention/management strategies, are listed in Table 3 [21]. Respiratory depression is the most serious; itching, constipation, and nausea or vomiting are common; other side effects are less common.

Many postoperative analgesic regimens rely upon a patient to self-administer analgesics. For example, a patient may be given a prescription for tablets and instructed to take one every few hours as needed. Patient controlled analgesia (PCA) devices are programmable by the healthcare provider to deliver a specific amount of medication upon each request by the patient. A continuous infusion may be co-administered in addition to patient controlled bolus doses. Bolus doses are limited by a programmed lockout interval within which successive requests are ignored or have a cumulative limit to drug dose permitted in a fixed interval. A PCA may be applied via intravenous, subcutaneous, transdermal, epidural or intrathecal routes. PCA provided better pain control than nonpatient controlled analgesia. Pain intensity on a visual analog scale (VAS) was statistically significantly lower in participants using PCA versus those receiving non-patient controlled analgesia at all time intervals [26].

Breakthrough cancer pain (BTcP) has been reported to be a pertinent problem in cancer patients with pain. It is hard to have a clear idea on a complex phenomenon without a prospective evaluation and an optimized analgesic approach.

For these reasons, it is likely that BTcP should be more correctly defined as an episode of severe intensity in patients receiving an adequate treatment with opioids able to provide at least mild analgesia. The principal pharmacological treatment of BTcP is represented by the administration of opioids as needed. Oral opioids, particularly oral morphine, have been the mainstay approach for the management of BTcP. Oral morphine has been given for years in doses proportional to

Table 3: Managing side effects

Side effects	Prevention/management notes
Respiratory depression	Screen for sleep apnea and avoid opioids if moderate-to-severe sleep apnea is present. Avoid prescribing opioids with sedatives, hypnotics, benzodiazepines, barbiturates, and alcohol. Educate and prescribe naloxone.
Itching	Reduce dose and increase frequency, change opioid, and/or consider a nonsedating antihistamine (e.g., cetirizine).
Nausea or vomiting	Consider prophylactic antiemetic therapy. Ondansetron (Zofran) is recommended because it does not interact with opioids. Use caution when prescribing ondansetron with drugs that cause serotonergic effects such as tramadol and tapentadol.
Constipation	Increase fiber and fluids; start with a mild peristaltic stimulant with a stool softener; increase dose if no BM in 48 hours. Second-line, more-expensive medications include a new category of constipation medications for opioid-induced constipation. Despite availability, they are not considered first-line.
Serotonin syndrome	Avoid combining opioids (particularly tramadol) with medications that increase serotonin.
Sexual dysfunction	Rule out other causes. Reduce dose.
Cognitive effects (such as sedation, confusion)	Reduce dose and/or change opioid; avoid sedatives.
Perceptual effects (e.g., hallucinations, depression)	Rule out other causes, and eliminate all nonessential CNS-acting medications (e.g., steroids). Reduce opioid dose, or switch opioid.
Hyperalgesia	Hyperalgesia results in peripheral and/or central sensitization. Symptoms include widespread pain not consistent with physical findings and/or pain out of proportion to mild stimuli. Animal studies note a lower pain threshold after exposure to sustained opioids. Reduce the dose, taper the patient off opioid medication, or rotate the opioid.

opioid doses used for background analgesia. Oral transmucosal fentanyl citrate (OTFC) was the first product approved for BTcP. A dosage unit resembles a lollipop or lozenge on a stick, and consists of a fentanyl impregnated sweetened lozenge on a plastic handle. The lozenge is gently rubbed against the buccal mucosa until it has completely dissolved (which should take no longer than 15 min, if appropriately used). Second-generation products have been shown to be superior to placebo and oral morphine. The fentanyl buccal tablet facilitates rapid absorption of fentanyl through the oral mucosa using an enhanced effervescent absorption technology. The intranasal administration of fentanyl may have some advantages, for example in patients with mucosal damages or salivary dysfunction. Two formulations of nasal fentanyl have been developed, an aqueous solution (INFS) as well as a pectin-based drug delivery system in the form of a gel designed to be applied to mucosal surfaces to optimize absorption [27].

Labor is another cause of pain that has been investigated. Evidence suggests that acupuncture and acupressure maybe effective for managing pain in labor. The pain experienced in labor is affected by the processing of multiple physiological and psychosocial factors, and where labor is proceeding normally, does not reflect an abnormal pathological process. Perceptions of labor pain intensity vary, and interventions used in pain management can have a primary focus of helping women to cope with pain in labor and in relieving pain. The intent of pain relief in labor from pharmacological interventions is to relieve pain and for non-pharmacological methods to cope with pain, although their intent and aims can vary with treatment administered. Evidence from these four systematic reviews of acupuncture and acupressure for labor suggests that acupuncture and acupressure techniques show promising point specific effects and overgeneralized holistic effectiveness in the support and management of pain in labor and birth, and the results are varied [28]. Smart implants can have a reactive role by delivering drugs for chronic pain [6].

A goal for the future is to move from self-reported outcomes, which require the active participation of the clinician, to measures that can be passively calculated from the medical record. Such measures as adequacy of pain management, respect for privacy, quality of communication, and overall satisfaction with anesthesia care can only be gathered from the patient's perspective. To effectively turn data into information, registries must find ways to creatively analyze what they collect and intuitively present it to their stakeholders [1].

4. Big Data in Pain Management

Analgesic efficacy can be improved by targeting pain mechanisms that are specific for different conditions: fibromyalgia (FM), osteoarthritis (OA), rheumatoid arthritis (RA), and neuropathic pain (NP), and by improving the safety

of the current analgesics, such as opioids. GLORIA focuses on the role of glial activation by tissue and nerve injury, inflammation, and high doses of opioids in both large cohorts of chronic pain patients and in respective experimental disease models. A panel of human pain-associated genes has been developed for a next generation sequencing workflow to study opioid and toll-like receptor genes and bioinformatics tools for the analysis of "big data". GLORIA will increase our understanding of the mechanisms (molecular, systems biological, genetic, behavioral) of pain in inflammatory (rheumatoid arthritis, osteoarthritis), neuropathic (nerve injury, diabetes) and dysfunctional (fibromyalgia) pain. GLORIA will also elucidate the changes that take place, particularly in the central nervous system, with time due to tissue or nerve injury and inflammation. All this information will also facilitate future analgesic drug development. GLORIA will institute improvement in clinical diagnosis, early intervention, and more personalized therapy for persistent pain. This would enable early introduction of pain relieving therapy and non-pharmacological interventions which can be used proficiently to prevent the development of widespread pain [29].

It's a scenario that CancerLinQ intends to address by pooling the real-time experience of treating millions of cancer patients in a big data computer system. Any oncology practice can log in and search for patients with profiles like theirs, and look up how they were treated and what their outcomes were. The project is billed as a rapid learning system for cancer, with the key mission to advance the quality of everyday oncology practice across the country. It can also be used to test hypotheses for clinical trials, generate new clinical guidelines, and bring in results from trials, registry data, and patient reported outcomes. The goal of CancerLinQ is to aggregate and analyze data from millions of cancer patients to identify new areas of research, but especially to improve care by feeding back to oncologist information on how well they are serving patients, according to quality guidelines. There is a drive to monitor and improve healthcare quality, but existing methods have reached their limits. The data collected comprises both structured information – such as the pathology and treatment of the cancer, and mandatory reports like standard scales of pain and emotional distress – and unstructured data, which are mainly the notes that accumulate for each patient. CancerLinQ has a lot of administrative and technical issues that have had to be solved, such as deidentifying the data and guaranteeing data are collected for the same person over time, so that comprehensive comparisons can be made, and how they fared at least for five years [30].

Research into cancer pain is organized and classified using big data because there is so much data including data from the patient, genomics, and other data. Big Data was applied so researchers could analyze the complete, raw genomic data sets of multiple patients in parallel, along with patient data records, detail selection data, and reference genome data. Analysis on the complete, unreduced data set can be performed by block of data and by patient. Using this new parallelization technique, the analysis on the complete data set can be completed between five and twenty minutes. The ability to dramatically reduce the time to analyze genomes and identify granular aspects such as Exon gaps in the analysis can help revolutionize the medical field. This creates tremendous opportunities for healthcare, biotechnology and government research organizations to apply genomic research to a wide variety of fields, and can help the entire healthcare industry apply personalized treatments that can radically change patient care [31].

5. Conclusion

Healthcare systems engineering is a key field that is especially affected by several key problems such as privacy, security of the data, collection of the data, and how much unstructured data is available for analysis. It is imperative that healthcare providers embrace innovative technologies and apply them to patient care to advance medicine. Big data can be used to shape healthcare systems, achieve better outcomes, and lead innovation.

Treatment for chronic pain has rapidly become a specialty that has numerous complications and requirements. The use of narcotics is associated with many side effects and problems such as respiratory depression, overdose, misuse, etc. Providers need a method to evaluate the data from various outlets including social media, smartphone apps, wristbands, etc. Big data in pain management offers unique and critical options for managing the voluminous amounts of data generated and promotes the application of personalized medicine.

The advent of personalized medicine offers healthcare providers the opportunity to implement better outcomes for their patients. Cancer pain can be a significant problem with control difficult. It is necessary that researchers have access to a broad base of datasets which can be searched by providers to ensure the most comprehensive care possible. Acupuncture can be a solid alternative to opioids in certain pain management cases. It is vital that providers, nurses, healthcare professionals work together to ensure patients have the best access to pain management care, the most comprehensive assessments to determine efficacy, and re-evaluation, and data to notify the provider when to discontinue the narcotics based on side effects or reduction of pain and improvement of function. Several pain assessments are available to provide that data however, big data is key in providing the answer to mining crucial information from large datasets. Future research needs to concentrate on opioid use, drug addiction, and better alternatives to narcotics.

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