Original Article

The Role Of Digital Radiography In Musculoskeletal Imaging: A Review Article

Ms. Gauri Awathale[1], Mr. Suhas Tivaskar[2], Mr. Anurag Luharia[3], Dr. Rajasbala Dhande[4], Aniket Pathade[5]

1] UG Student, B.Sc. MRIT (Medical Radiology and Imaging Technology), Department of Radiology, School of Allied Health Science, Datta Meghe Institute of Medical Sciences, Wardha, Maharashtra, India.
2] Assistant Professor, MRIT (Medical Radiology and Imaging Technology), Department of Radiology, School of Allied Health Sciences, Datta Meghe Institute of Medical Sciences, Wardha, Maharashtra, India.
3] Assistant Professor, MRIT (Medical Radiology and Imaging Technology), Department of Radiology, School of Allied Health Sciences, Datta Meghe Institute of Medical Sciences, Wardha, Maharashtra, India.
4] HOD & Professor, Department of Radiology, Jawaharlal Nehru Medical College, Datta Meghe Institute of Medical Sciences, Wardha, Maharashtra, India.

Corresponding author's name and address: Mr. Suhas Pruthviraj Tivaskar Assistant Professor, MRIT (Medical Radiology and Imaging Technology), Department of Radiology, School of Allied Health Sciences, Datta Meghe Institute of Medical Sciences, Wardha, Maharashtra, India
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Abstract

Background: Digital radiography is a type of imaging that employs an x-ray-sensitive cassette to display information digitally so doctors may see it as they examine a patient. Without an image receptor, the data is transmitted instantaneously to a computer. As a result of DR, both the amount of radiation and the total price decreased. Portable digital radiography is very helpful for examining the musculoskeletal system of trauma victims. These qualities are especially useful in musculoskeletal applications. This can reduce the radiation dose and the number of exposures in clinical settings. We evaluated digital radiography's potential in diagnosing musculoskeletal problems by comparing its image quality to that of traditional film and film screens to determine whether or not it is an improvement over the latter. Frequency-modified digital imaging outperformed film at differentiating soft-tissue structures and identifying regions with significant attenuation differences. The traditional film-screen technology was great at portraying minute anatomical details and pinpointing the area around prostheses. This was due to the unsettling halo effect surrounding the prosthesis in digital photographs, as opposed to the excellent spatial resolution of the conventional film approach. The unsharp masking operator responsible for the halo effect was not adjusted for any individual tests in this set. It is possible to use the digital system to cut the radiation dose (exposure) by half without compromising data. In our facility, musculoskeletal imaging is performed using digital radiography (DR) rather than screen-film (S.F.). Due to our ongoing process of improving image quality, our DR images are now favoured over Screen Film images, and we have explained our current optimal settings for the Fuji 9000. (Fuji Medical Systems, Tokyo, Japan). Advantages of DR include higher contrast resolution, variable picture contrast, image reprocessing, and simple image-to-image management and communication system transfers (IMAC).

Keywords: Digital Radiography, Resolution, musculoskeletal, Image Optimal Image, Spatial Resolution,

INTRODUCTION

Digital radiography (DR) for the musculoskeletal system is widely employed in the medical diagnostic imaging system (MDIS) program and elsewhere. It is often considered an adequate reserve for screen-film (S.F.) radiography **[1].** Images similar to those seen on a cinema screen have been created in previous research by adjusting parameters in the image processing software. **[2-3]** The first digital radiography systems we evaluated confirmed our suspicions that the manufacturer's recommended image processing settings did not always yield a suitable image for interpretation. Better abnormality visibility is one reason digital radiography of the musculoskeletal system is preferred over conventional radiography.

A resolution was comparable to our previous screen-film technology, benefits in offering a range of contrast levels, and the ability to reprocess images using the same source material. In the hospital and the emergency room, we have switched to digital radiography from traditional radiography. Within a year, we want to have changed from screen-film radiography to digital radiography in our outpatient section. We consider the image quality of DR to be superior to the exposure quantity used in our 100-speed system. However, achieving higher-intension images on screen-film systems with higher exposures is still possible. **[1]** The quality of an image can be altered by several variables, such as the method of image acquisition, the type of display device used, and the type of display mode used. Evaluation and improvement of image quality can occur at either the purchase or presentation end of this imaging continuum, thanks to the modular nature of digital systems. How we evaluate images' quality varies from task to task **[4-5].** While digital radiography has several applications in imaging (including the chest, musculoskeletal system, and genitourinary system), there is a universal threshold for acceptable image quality. This work and its companion paper on image accession are based on research in scholarly medical journals. In this case, the study focuses on the process of picture clarification and the presentation of digital radiography images. The introductory section of the complementary work on picture accession provides a standard definition of digital radiography. Briefly, in this guide, the phrase "digital radiography" encompasses both traditional digital radiography and its predecessor, computed radiography. Cassette radiography and less frequent use of digital radiography fall under the scope of this recommendation. **[6]**

ASSURING THE QUALITY IMAGE

The replacement of screen film with DR is insufficient to provide high-quality images with a DR system. Since there are substantial distinctions between the two systems, technology specialists must be trained to work with both. To achieve high-quality images, selecting the smallest imaging plate feasibly is essential and using high-resolution imaging plates appropriately. Proper collimation and exposure time are needed. Modifications must be made to the data used in image processing to obtain the most information. In prior sections **[1-7],** we laid out the steps we take to get optimal performance. At first, receive paired images from both the S.F. and DR cameras. The DR images are set up to generate numerous images from each data set by carefully adjusting the limit parameters. Keeping detailed records of preferences and facts was preferable to methods that hid information. This procedure is repeated until satisfactory results are achieved for all body parts in the images.

RESOLUTION

High-resolution imaging plates for all limbs (hands, arms, elbows, wrists, ankles, and feet) are required for adequate resolution. Around 4.5lp/mm high-contrast resolution is provided by the imaging plates with high resolution. **[1]**

BENEFITS OF DR FOR THE SKELETAL AND MUSCULAR SYSTEM

High resolution, a flexible range of contrast & brightness, the ability to reprocess images to obtain additional information, and using DR as an entry point into image management and communication system [IMAC] are what we have found to be the most significant benefits of digital radiography of the musculoskeletal system. **[1]**

USE OF DR WITH IMAGE REPROCESSING TO PROVIDE A MORE OPTIMAL IMAGE

Initial image processing is subpar due to a mismatch between the patient's size and form and the quality preset in the algorithm. In such a circumstance, refining the digital data can often eliminate the need for further radiographs.

ADJUSTING THE RANGE OF CONTRAST

Raising or lowering the contrast ratio can improve the legibility of structures. Because of the varying densities in the final image, specific radiographic images, such as those of the hip, the base of the skull, zygomatic arch, and nasal bone, are impossible to obtain. After adjusting the contrast range or receiving two separate imaging-processing settings, better detail can be seen in buildings. In a correct lateral view of the hip, this intertrochanteric fracture has healed better than is typical. This is due to the more excellent latitude value producing a picture with less contrast.

REPROCESSING OF IMAGES TO OBTAIN ADDITIONAL INFORMATION

Occasionally, a radiography image may reveal the presence of a secondary pathology. The additional information in these circumstances may allow for a more precise diagnosis with the help of further image processing. The displaced sixth cervical vertebra on the seventh cervical vertebra is seen in this retouched picture. After the image was reprocessed, it was clear that a little plug of methacrylate had been used to fill a gap throughout the screw, but when the screw was removed, the methacrylate came out with it, indicating that the hole had been filled. **[1]**

DIGITAL RADIOGRAPHY OF MUSCULOSKELETAL USING STIMULABLE PHOSPHOR

When used in skeletal radiology, digital radiography can offer several advantages over older film-screen methods, including better image preservation, transmission, processing, and display **[8-9].** Exciting developments in musculoskeletal imaging include image processing and the manipulation of picture contrast and density, which may lead to more accurate information about soft tissues than is now possible with radiography alone. Insufficient spatial resolution **[10, 11]** may be a drawback of digital musculoskeletal radiography. However, there is a lack of clinical expertise in digital musculoskeletal radiography. Here, we provide our experience with a preliminary implementation of digital radiography in the clinical practice of musculoskeletal radiology.

The focus of the present investigation was to evaluate the perfection with which anatomic structures could be illustrated with the two imaging systems at varying radiation and to compare the model with which important features of common musculoskeletal wounds could be displayed and assessed with the two imaging systems.

PERFORMANCE OF KNEE IMAGE DIGITAL ANALYSIS OF RADIOGRAPH OF PATIENT WITH END-STAGE KNEE

Radiographs taken when the patient is bearing weight anterior-posteriorly or posteroanterior (PA) are typically used to evaluate these features in osteoarthritic knees **[12].** Although imaging modalities like M.R.I. are growing, radiography remains the oldest approach for diagnosing and monitoring knee Osteo Arthritis. Patients with mild knee Osteo Arthritis, as shown by their average Kallgren & Lawrence (K&L) grade of 1.3, were initially used to demonstrate the usefulness and validity of the limitations of the Knee Image Digital Analysis (KIDA), and measurements were performed to differentiate these patients from healthy controls.

A standardised, semi-flexed P.A. radiograph was done below full weight-bearing according to the ‘Buckland’–Wright technique **[13-14].** An aluminium step wedge was put next to the knee, against the detector. Within the exposure, aluminium evaluates bone density and finds the pixel size after correcting for possible magnification. Before therapy (baseline), throughout treatment, and at 1- and two years post-treatment, radiographs were taken.

SPATIAL RESOLUTION REQUIREMENTS FOR DETECTION OF SUBPERIOSTEAL RESORPTION

Better-resolution skeletal radiography, like the septal lines in chest imaging, is used by several facilities to detect subperiosteal resorption in the phalanges **[15, 16]**. Subperiosteal resorption has been widely recognised as a practical test for digital radiology systems due to its reputation as one of the most resolution-intensive skeletal imaging scenarios.

To better understand the progression of secondary hyperparathyroidism in patients with chronic renal failure, we have digitised direct magnification hand radiographs. An analogous collection of standard radiographs was also digitised. The digitised photos were computer-processed to create images with varied spatial resolutions. Processes were applied to each digitised image to keep the contrast range uniform. The diagnostic requirements were established by comparing the average of the processed images with the standard of the original films using Receiver Operating Characteristic (ROC) analysis. **[17]**

SPECIFIC MUSCULOSKELETAL APPLICATION

The level of detail obtained by portable film-screen radiography is typically lower than that obtained from exams employing more complex scatter suppression techniques and takes numerous, repeated exposures to achieve acceptable quality. While fewer re-exposures are required thanks to DR's robust linear response, detail is better-seen thanks to digital processing's ability to enhance edges. Portable musculoskeletal tests are one of the most prevalent applications of DR technology, where it is essential in imaging patients with severe trauma. The patient's spine, chest, pelvis, and extremities are imaged using mobile computed radiography. Our hospital employs DR for 18% of its total workload, making it the standard for portable ED exams. Like the skeletal radiologist, we have found that doctors prefer DR images over traditional radiographs. **[18]**

TECHNICAL CONSIDERATIONS

The storage phosphor in DR systems takes the film’s place on a standard TV set (photostimulable phosphor). Traditional radiographic imaging equipment and techniques are employed, and the phosphor imaging plate is housed in a film cassette. Fine-grained (5-10 um) barium fluorohalide crystals doped with divalent europium form the phosphor layer on the bendable image plate. This is mixed with a binder and spread across a thin layer of protective film. Similar to screens, the image plates necessitate delicate handling. Dust buildup is a typical cause of artefacts; hence it is advised that plates be cleaned once a week. To begin with, the imaging plate is exposed to incoming radiation, which excites electrons to higher energy levels (conduction band) (X-rays). **[18]**

RADIATION DOSE REDUCTION

For most musculoskeletal assessments, DR can reduce radiation dose (less exposure and fewer repeat examinations) without seemingly sacrificing diagnostic accuracy. From what we've seen and heard from others, it seems that a 25-50% reduction in exposure is conceivable compared to the conventional film-screen method **[19,20].** We conducted a direct qualitative comparison (Murphey MD et al., ARRS meeting, May 1991) of DR and traditional radiography in several standards and pathological musculoskeletal examinations at varied percentage exposures, which differ from conventional procedures by reducing milliampere seconds. Lower exposure levels led to a decline in the percentage of superior phosphor plate images (43% at 100% exposure and 26% at 75% exposure) and an improvement in the rate of conventional radiographs graded as equivalent or better than their corresponding phosphor plate image (3% at 100% exposure and 4% at 75% exposure). Despite this, 93% of DR pictures were rated as better than or on par with their traditional radiograph counterparts when using a 50% exposure approach. Images captured by phosphor plates get increasingly grainy when the exposure time is shortened (owing to quantum mottle). The result of which is a reduction in spatial precision. The increased X-ray attenuation during central musculoskeletal tests (spine, pelvis, hips) makes this noise even louder. Our evaluation of observer performance uncovered a striking contrast between the diagnostic validity of DR pictures at 50% exposure and that of conventional radiography in these settings (**Murphey MD et al**., ARRS meeting, May 1991). Exposures similar to traditional radiography allow more precise imaging of these core regions and patients with substantial body habitus. Contrarily, at least half the standard exposure time can be eliminated from the procedure for radiography of the periphery without compromising image quality. There is no well-defined standard for determining the most significant radiation dose reduction attainable without compromising diagnostic validity DR for individual tests. There will be a tradeoff between increased noise and the necessary spatial resolution. Therefore, these thresholds will vary depending on the type of deformity and the anatomical position of the radiograph. **[21-30]**

DISCUSSION

Only significant bones and joints, including the spine, were analysed in this study. Conventional methods, digital radiography of the hands and feet, and more expert film-screen and exposure circumstances, including the mammographic technique and magnification, should all be compared and contrasted. As a result, the current study did not focus on these anatomical regions. In musculoskeletal radiology, the contrast and density manipulation benefits for improving data on soft tissues, and the low spatial resolution drawbacks, are the most important differences between the digital system and conventional radiography.

As evidenced by the findings given. Radiographic investigation of Osteo Arthritis (OA) features is aided by Knee Image Digital Analysis (KIDA), even in individuals with advanced OA. It is important to note that rapid reanalysis of photos increases repeatability (decreases SDDs and decreases systematic bias between measurements). This highlights the significance of conducting time- and sequence-randomized analyses within a limited window to answer a focused research issue. One observer is preferable to several observers when analysing photos since there is more of a chance for error when more people are involved in the process. In this case, the digital radiography was properly configured and applied. Therefore, the resulting images were of high quality. High image quality stability and sufficient resolution are provided. In musculoskeletal radiography, it is possible to reduce exposure by 25–50%. In addition to the other images produced for each trial, a musculoskeletal radiologist also retrospectively analysed the decline images and the repetition photos in their timed sequence for the musculoskeletal. **[31-37]**

CONCLUSION

These benefits, especially the enhanced dynamic range and image processing capabilities, are particularly useful in musculoskeletal radiography applications. We've made an effort to detail and exhibit both the benefits (lower radiation exposure, fewer repeat exams, more thorough examination of the spine, soft tissue, and portable studies) and drawbacks (high cost, limited throughput, lower spatial resolution, higher noise, and a shift in image size and format) of DR in musculoskeletal imaging.

REFERENCES

1. Freedman M, Steller D. Digital radiography of the musculoskeletal system: The optimal image. Journal of digital imaging. 1995 Feb;8(1):37-42.

2. Wilson AJ, Mann FA, Murphy Jr WA, Monsees BS, Linn MR. Photostimulable phosphor digital radiography of the extremities: diagnostic accuracy compared with conventional radiography. AJR. American journal of roentgenology. 1991 Sep;157(3):533-8.
3. Kreipke DL, Silver DI, Tarver RD, Braunstein EM. Readability of cervical spine imaging: Digital versus film/screen radiograph Computerisedized medical imaging and graphics. 1990 Mar 1;14(2):119-25.
4. International Commission on Radiation Units and Measurements. ICRU report 54, medical imaging the assessment of image quality. Bethesda, Md: International Commission on Radiation Units and Measurements; 1996.
5. Beutel J, Kundel HL, Kim Y, Van Metter RL, Horii SC. Handbook of medical imaging. Spie Press; 2000.
6. Krupinski EA, Williams MB, Andriole K, Strauss KJ, Applegate K, Wyatt M, Bjork S, Seibert JA. Digital radiography image quality: image processing and display. Journal of the American College of Radiology. 2007 Jun 1;4(6):389-400.
7. Nelson MC, Freedman MT, Einar VP, Lo SC, Smith DV, Leckie RG, Mun SK. Image processing of storage phosphor musculoskeletal radiographs: a comparison of the AGFA and Fuji bone algorithms. InMedical Imaging 1994: Image Processing 1994 May 11 (Vol. 2167, pp. 854-867). SPIE.
8. Merritt CR. Computed radiography: a new approach to plain film imaging. Diagnostic Imaging. 1985 Jan; 1:58-65.
9. Sonoda M, Takano M, Miyahara J, Kato H. Computed radiograutilisingzing scanning laser stimulated luminescence. Radiology. 1983 Sep;148(3):833-8.
10. Chan HP, Vyborny CJ, MacMahon H, Metz CE, Sickles EA. Digital mammography. ROC studies the effects of pixel size and unsharp-mask filtering, detecting subtle microcalcifications. Investigative radiology. 1987 Jul 1;22(7):581-9.
11. Nakano Y, Hiraoka T, Togashi K, Nishimura K, Itoh K, Fujisawa I, Sagoh T, Minami S, Itoh H, Torizuka K. Direct radiographic magnification with computed radiography. American Journal of Roentgenology. 1987 Mar 1;148(3):569-73.
12. Vignon E, Piperno M, Le Graverand MP, Mazzuca SA, Brandt KD, Mathieu P, Favret H, Vignon M, Merle-Vincent F, Conrozier T. Measurement of radiographic joint space width in the tibiofemoral compartment of the osteoarthritic knee: comparison of standing anteroposterior and Lyon schuss views. Arthritis & Rheumatism. 2003 Feb;48(2):378-84.
13. Buckland-Wright JC, Ward RJ, Peterfy C, Mojcik CF, Leff RL. Reproducibility of the semiflexed (metatarsophalangeal) radiographic knee position and automated measurements of medial tibiofemoral joint space width in a multicenter clinical trial of knee osteoarthritis. The Journal of Rheumatology. 2004 Aug 1;31(8):1588-97.
14. Buckland-Wright JC, Wolfe F, Ward RJ, Flowers N, Hayne C. Substantial superiority of semiflexed (MTP) views in knee osteoarthritis: a comparative radiographic study, without fluoroscopy, of standing extended, semiflexed (MTP), and schuss views. The Journal of Rheumatology. 1999 Dec 1;26(12):2664-74.
15. Uchida K, Watanabe H, Aoki T, Nakamura K, Nakata H. Clinical evaluation of irreversible data compression for computed radiography of the hand. Journal of digital imaging. 1998 Aug;11(3):121-5.
16. VÖLK M, Strotzer M, Gmeinwieser J, Alexander J, FRÜND R, Seitz J, Manke C, Spahn M, Feuerbach S. Flat-panel X-ray detector using amorphous silicon technology: reduced radiation dose for the detection of foreign bodies. Investigative radiology. 1997 Jul 1;32(7):373-7.
17. Murphey MD. Digital skeletal radiography: spatial resolution requirements for detection of subperiosteal resorption. American Journal of Roentgenology. 1989 Mar 1;152(3):541-6.
18. Milos MJ, Aberle DR, Baraff LJ, Gold RH, Scanlan RL, Bassett LW. Initial clinical experience with computed radiography imaging in an emergency department. Applied Radiology. 1989 Jan 1;18(1):32-7.
19. Prokop M, Galanski M, Oestmann JW, Von Falkenhausen U, Rosenthal H, Reimer P, Nischelsky J, Reichelt S. Storage phosphor versus screen-film radiography: effect of varying exposure parameters and unsharp mask filtering on the detectability of cortical bone defects. Radiology. 1990 Oct;177(1):109-13.
20. Pettersson H, Aspelin P, Boijsen E, Herrlin K, Egund N. Digital radiography of the spine, large bones, and joints using stimulable phosphor: early clinical experience. Acta Radiologica. 1988 May;29(3):267-71.
21. Murphey MD, Quale JL, Martin NL, Bramble JM, Cook LT, Dwyer 3rd SJ. Computed radiography in musculoskeletal imaging: state of the art. AJR. American journal of roentgenology. 1992 Jan;158(1):19-27.
22. Mettler Jr FA, Huda W, Yoshizumi TT, Mahesh M. Effective doses in radiology and diagnostic nuclear medicine: a catalog. Radiology. 2008 Jul;248(1):254-63.
23. Bali, Thool, Lokhande Shalini, A. Lalawmpuii, Ambule Kalyani, Shendre Vaishnavi, and Warghane Roshani. “Case Report on Primary Infertility with Hypothyroidism and Diabetes Mellitus.” Journal of Pharmaceutical Research International, December 15, 2021, 263–66. https://doi.org/10.9734/jpri/2021/v33i58B34202.
24. Bandela, Vinod, Ram Basany, Anil Kumar Nagarajappa, Sakeenabi Basha, Saraswathi Kanaparthi, Kiran Kumar Ganji, Santosh Patil, Ravi Kumar Gudipaneni, Ghazi Sghaireen Mohammed, and Mohammad Khursheed Alam. “Evaluation of Stress Distribution and Force in External Hexagonal Implant: A 3-D Finite Element Analysis.” International Journal of Environmental Research and Public Health 18, no. 19 (September 29, 2021): 10266. https://doi.org/10.3390/ijerph181910266.
25. Bankar, Nandkishor, Gangaram L. Bhadarge, Neha Bhatt, and Rakesh Kumar Jha. “Study of Haematological and Biochemical Parameters of COVID-19 Patients in ICU and in Ward.” Journal of Pharmaceutical Research International, December 15, 2021, 442–48. https://doi.org/10.9734/jpri/2021/v33i58A34136.
26. Bankar, Nandkishor, Dhruba Hari Chandi, Praful Patil, and Gaurav Mahajan. “Comparative Antibiogram of Escherichia Coli Isolated from the Urinary Tract Infection in Patients from Tertiary Care Hospital.” Journal of Pharmaceutical Research International, July 7, 2021, 123–28. https://doi.org/10.9734/jpri/2021/v33i35B31910.
27. Bansal, Riya, G. D. Vishnu Vardhan, and Ashish Bele. “Impact of Pre-Operative Coping Strategies and Exercises on Post-Operative Recovery and Quality of Life of Patients with Cancer Having Depression.” Journal of Pharmaceutical Research International, October 2, 2021, 402–11. https://doi.org/10.9734/jpri/2021/v33i45A32759.
28. Bansod, Shashank, and Bhushan Madke. “Non-Immunological Contact Urticaria (NICU) Due to Ethanol Containing Hand Sanitiser: A Case Report.” JOURNAL OF CLINICAL AND DIAGNOSTIC RESEARCH, 2021. https://doi.org/10.7860/JCDR/2021/45990.14462.
29. Bante, Vaishnavi, Vaishali Rahate, Rahul Dixit, Rakesh Kumar Jha, and Roshan Kumar Jha. “Self-Medication Practices: A Threatening Challenge.” Journal of Pharmaceutical Research International, July 21, 2021, 21–25. https://doi.org/10.9734/jpri/2021/v33i38A32055.
30. Bauer, Michael, Tasha Glenn, Eric D. Achtyes, Martin Alda, Esen Agaoglu, Kürşat Altınbaş, Ole A. Andreassen, et al. “Variations in Seasonal Solar Insolation Are Associated with a History of Suicide Attempts in Bipolar I Disorder.” International Journal of Bipolar Disorders 9, no. 1 (December 2021): 26. https://doi.org/10.1186/s40345-021-00231-7.

31. Bawane, Shiva, Manjusha Mahakalkar, and Ruchira Ankar. "A Case Report on Severe Acute Respiratory Infection." Journal of Pharmaceutical Research International, December 14, 2021, 206–10. https://doi.org/10.9734/jpri/2021/v33i57B34047.

32. Bawankar, Payal, and Savita Pohekar. "To Assess Effectiveness of Informational Booklet on Knowledge Regarding Bardet- Biedl Syndrome among Nursing Students." Journal of Pharmaceutical Research International, October 30, 2021, 861–65. https://doi.org/10.9734/jpri/2021/v33i47A33085.

33. Bawiskar, Dushyant. "A Case Report on Physiotherapy Rehabilitation of Patient with Lacunar Infarct." Bioscience Biotechnology Research Communications 14, no. 6 (June 15, 2021): 01–04. https://doi.org/10.21786/bbrc/14.6.1.

34. Bawiskar, Dushyant, and Pratik Phansopkar. "Efficacy of Agility Training in a Police Cadet: A Case Study." Journal of Pharmaceutical Research International, July 24, 2021, 281–87. https://doi.org/10.9734/jpri/2021/v33i38A32087.

35. Bawiskar, Nipun, Aamil Rasheed, Jahnabi Bhagawati, and Sourya Acharya. "Transient Myocardial Ischemia in a Case Post Intra-Muscular Adrenaline." Journal of Pharmaceutical Research International, December 17, 2021, 36–40. https://doi.org/10.9734/jpri/2021/v33i59B34349.

36. Bawiskar, Nipun, Dhruv Talwar, Sourya Acharya, and Sunil Kumar. "Hematological Manifestations of COVID-19 and Their Prognostic Significance in an Intensive Care Unit: A Cross-Sectional Study." Cureus, November 25, 2021. https://doi.org/10.7759/cureus.19887.

37. Beedkar, Aishwarya Uday. "A Review of Impact of COVID-19 Pandemic on Medical and Healthcare Fraternity." Bioscience Biotechnology Research Communications 14, no. 6 (June 15, 2021): 247–52. https://doi.org/10.21786/bbrc/14.6.51.